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COMMONWEALTH OF PENNSYLVANIA

DEPARTMENT OF HIGHWAYS

SURVEY MANUAL

INSTRUCTION TO SURVEY CORPS

HARRISBURG, PENNSYLVANIA

1965

INTRODUCTION

This Survey Manual has been prepared and placed in your hands by the Pennsylvania Department of Highways, to be studied and used as a guide in the production of uniform, complete and accurate surveys.

An employee of the Pennsylvania Department of Highways is a part of a large construction and service organization, the operating cost of which is paid directly by the people of this Commonwealth. As the members of a survey party are usually the first to make direct contacts with the local citizens, the Department is judged by your actions, and your respect for public and private property.

Employees are encouraged to send constructive criticisms and suggestions to their district engineer, who will review them and in turn forward with his comments to the Chief Engineer. If such suggestions meet with approval the portion of the Manual affected will be revised and new sheets released to the field. When submitting suggestions indicate the portion of the Manual affected by chapter number, pages and paragraphs; the weakness of the existing instructions or procedure, and the advantage claimed for the proposed suggestion.

02614

SURVEY MANUAL

Table of Contents

Chapter	Subject	Page
	Introduction	i
	Table of Contents	ii
1	General Instructions	1–1
2	Organization of Corps	2–1
3	Classification of Highways (Design Criteria)	3–1
4	Chain Surveys	4–1
5	Surveys for Low Cost Construction	5–1
6	Reconnaissance Surveys	6–1
7	Traverse Surveys	7–1
8	Preliminary Surveys	8–1
9	Aerial Surveys	9–1
10	Bridge and Culvert Site Surveys	10–1
11	Construction Surveys	11–1
12	Borrow Pit Surveys	12–1
13	Final Surveys	13–1
14	Condemnation of Right of Way Surveys	14–1
15	Care and Preparation of Notebooks—Symbols	15–1
16	Equipment and Supplies	16–1
17	Reports—Forms	17–1
18	Useful Information	18–1
19	Electronic Data Processing Traverse Computations	19–1
	Index	19–8
	Index Useful Information	19–13
	Index Tables	19–14
	Index Figures	19–15

CHAPTER ONE

GENERAL INSTRUCTIONS

1–1 Upon the chief-of-party falls the responsibility of performing the work according to the highest standard of efficiency. He is responsible for maintaining the schedule established for the survey, as well as the cost and accuracy of the work. The members of a survey party should be active, intelligent and have a background in surveying experience consistent with the position they hold.

1–2 By the Act of April 22, 1937, P. L. 393 and in compliance with the amendment in paragraph 1–3, the right is conferred upon the Department of Highways to enter upon private property for the purpose of making surveys. The Act provides that any damages sustained by any owner of land entered upon shall be determined and paid according to law, and it further provides a penalty for interferring with the rights of the Department. However, this right should not be abused and private property should be respected at all times.

1–3 Article IV, Section 409 of Act No. 6 cited as the "Eminent Domain Code", as enacted by the General Assembly in 1964, amends P. L. 393 in as much that the Department or its agents shall have the right to enter upon private property in order to make surveys, studies, tests, soundings, and appraisals, provided that the owner of the land or the party in whose name the property is assessed has been notified ten (10) days prior to entry on the property. Except, in emergency situations wherein sufficient time is not available to notify property owners a "Waiver of 10-Day Notice" (Form 4192, Page No. 1-7) may be utilized to secure the right to enter when the property owner is amenable to such action. The following instructions should be adhered to in using Form 4192:

1. Address of property or other description thereof is to be filled in after words, "known as."

2. If owner/occupant insists that permission to enter be limited to a specified time period, fill in time limitation in blank space above date.

3. The executed waiver should be retained in the file of the party securing it.

4. If a waiver cannot be obtained entry must be delayed until 10-day notice can be given.

1–4 Included at the end of this chapter is a form letter (Form 383) each District is required to utilize in the prescribed manner prior to entering private properties for the afore mentioned purposes. Upon entry of private property the chief-of-party should make personal contact to discuss with the owner the handling of any livestock that might be contacted and answer any factual questions competently and courteously.

1–5 The Highway Department as a public service organization is judged by its employees' behavior, as well as by its work. Every employee should always bear in mind that the public judges the Department by the words and actions of the employees not only during but after working hours. Refrain at all times from loose talk, gossip or comments concerning the Department or its policies.

You have a definite responsibility in building public good will toward the Department.

1–6 Avoid littering at all times. Refrain from careless markings with crayon, ink or paint on road surfaces, trees, walks, etc. Poor conduct of this nature reflects immediately upon the Department.

1–7 Employees should make every effort to so conduct their personal financial affairs as to lend prestige to the position they hold with the Department. Complaints directed to the district or Central Office concerning employees accounts past due are detrimental both to the Department and the employee. Field employees who incur bills in towns in which they are located, due to work assignment, must pay such bills promptly. Your conduct in social and business matters outside your work will directly reflect credit or discredit upon the Department.

1–8 Courtesy is a prime requisite of every employee. This refers to answering questions, taking criticism, right or wrong, and accepting suggestions. Whenever you can answer a factual question, do so. If the question is a matter of policy or requests information you do not have, refer at once to your superior.

1–9 Always be helpful in warning traffic of hazards. When driving a personal or Department car, conform to all the rules of the road; more than that give way to the other motorist, especially so when driving a Department car. Try to be of assistance during accidents and helpful to other motorists who may need assistance. Survey corps buses shall be parked in such a manner as not to create a hazard to the public nor an obstacle to property owners. Many property owners will provide a safe area if consulted.

1–10 In all districts a capable, experienced employee shall be designated as a chief of surveys, to relieve the engineers and regulate the corps for maximum efficiency. He may be assisted in this function by an assistant chief of surveys if the work-load requires.

1–11 This is good practice when the amount of survey work and the number of corps warrant. In addition to scheduling the work of the various corps, he shall study all available data for reconnaissance, preliminary surveys and relocations and accompany the district engineer or his representative when making investigations or reconnaissance surveys. Later he and the chief-of-party walk the proposed alignment and spot the points of intersection and determine the approximate curvature. He is the direct contact between the district office and the corps and maintains a constant flow of survey notes to the drafting room.

1–12 The chief-of-party is directly responsible to the district engineer or his designated representative and shall obtain from him all necessary information and data to begin and complete the type of survey authorized. He is responsible for maintaining the highest standard of efficiency, keeping within the time schedule established, the cost of the survey, and the accuracy and completeness of the work. A survey shall have been authorized before a corps is placed on the project.

1–13 The district engineer or his representative shall designate where a corps shall stay while making a survey. From past investigation certain places in each locality have been selected where the prices are reasonable and the quarters comfortable.

1–14 The survey shall begin at the west or south end of the general direction of the route and the starting station shall be taken from and be a continuation of the straight line diagrams covering the limits of the survey. This information shall be furnished to the chief-of-party by the district office.

1–15 Field notes shall be computed and checked by the chief-of-party and/or competent members of the party. All field computations shall be computed and checked in the field. This work shall be very carefully performed as errors introduced at the beginning of a survey are sometimes not discovered until considerable additional and costly work has been performed.

1–16 The chief-of-party is held responsible for the correctness of the expense accounts of the members of his party, and if the expenditures as indicated represent actual disbursements in accordance with prevailing instructions, he shall approve them by signing his name in the space provided. Any attempt to pad expense accounts or charge items erroneously will result in immediate dismissal.

1–17 Each chief-of-party shall be furnished with a copy of the Safety Manual, issued by the Department and must observe the regulations as they apply to a survey corps, especially Regulation 621, concerning the use of flagmen as a protection when working on highways carrying heavy traffic.

1–18 Accidents to personnel must be reported in triplicate on Form LIBC-344, Employers Report of Industrial Injury, and all copies forwarded to the district office within forty-eight (48) hours.

1–19 In staking a survey observe the purpose for which the stakes are placed. In general the stakes placed on a Traverse Survey for the securing of preliminary information are temporary. The stationing will change and the stakes are generally used to locate the alignment. All reference stakes placed on preliminary surveys should be placed at the most convenient locations possible, so the alignment can be re-established with the least loss of time. When it becomes necessary to make a construction stakeout, then all stakes should be placed on an offset line beyond the limits of construction. All control points should be well referenced by stakes or permanent objects beyond the limit of construction.

1–20 Offset stakes shall be marked neatly and clearly with blue crayon or sunfast ink applied with a felt-tipped marking pen. The felt-tipped marking pen is available as a consumable supply through normal requistioning channels on Form 510. The station and/or plus shall be marked on the side towards center line and the distance to the center line or point to be located shall be marked on the side away from center line. When placed on center line the station and/or plus shall be marked on the side approaching the stake. When placing station stakes, stakes should be slanted slightly forward to protect stationing data from weathering.

1–21 Stakes placed in lawns, adjacent to walks or driveways, shall be driven flush with the ground surface and the location of each stake indicated by a flag or guard stake which shall extend above ground surface a distance of not less than thirty (30) inches. This is to provide maximum protection of pedestrian traffic.

1–22 Any surveyed center line should be so referenced to substantial and permanent objects as to enable reproduction at any later time. All reference

measurements are to be taken horizontally and to the nearest one-hundredth (0.01) of a foot and to at least three objects which form a well proportioned intersection.

1–23 Reference points shall be carefully selected so that they are easily accessible whenever it becomes necessary to re-establish the alignment. When a construction stakeout is made, all references must be placed beyond the limit of construction.

1–24 Great care should be used in the cutting of timber. Under no condition should trees or shrubbery in built-up sections be blazed for the purpose of referencing. When it is necessary to blaze any tree for a reference, the blazing should be done carefully so that the plant will not be permanently injured.

1–25 Special attention shall be given to the removal of foliage from wild cherry, wild crab apple, and locust trees that have been cut by survey corps in pastures, grazing fields, and similar livestock access areas. Wilted leaves and branches of these trees may cause death of livestock if consumed.

1–26 Stationing of all surveys and drawings shall correspond to the system established by our straight line diagrams.

1–27 The bearing of all surveys and plans should be based on True North, obtained either by observation on the sun or polaris or from a convenient and prior survey in the vicinity having true bearings. Exception to this rule is in the case where conditions are such that it would be impracticable or uneconomical to use other than magnetic bearings. Each plan should contain a definite reference (on the North arrow) as to the system of bearings used. All recorded plans must be based on true bearings.

1–28 All topography shall be referenced and shown, so that any qualified draftsman or engineer of the Department can immediately interpret and plot the notes. When advisable for accuracy and clearness, a separate sketch shall be shown in the back of the notebook and referred to in the survey notes.

1–29 Necessary precautions should be taken in preliminary studies and subsequent field and office work, to see that railroad right of way is not acquired or occupied without the consent of the railroad company. This is required in pursuance to an Act of June 21, 1935, P. L. 387.

1–30 When channel changes are involved, a property owner's riparian rights must not be overlooked. Without the consent of an affected property owner this Department cannot divert a stream so as to deprive him of water that normally served his property. Assuming that consent is obtained from all owners involved, then the matter resolves itself into one of economics; the comparative construction and property damage costs of the alternate methods available for handling the situation.

1–31 Before leaving the district office on a new assignment the chief-of-party should be furnished with all necessary data to intelligently perform the type of survey assigned. He should be informed as to the maximum allowable curvature, grades, minimum horizontal and vertical sight distances, width of proposed graded roadway, required right of way, present legal right of way, and classification of highway. He should be furnished with prints of the straight line diagrams needed, location and elevation of convenient U.S.G.S. or Department bench marks, pre-

vious survey or reconnaissance notes, route or application, and section number, authorization, survey schedule, and funds authorized. He should also check over his equipment and supplies.

1–32 Immediately upon arriving and engaging quarters, the chief-of-party must forward his mailing address and the number and location of the telephone, whereby he may be contacted at meal times and after working hours.

1–33 The survey should start with the stationing upon which the official mileage records, (straight line diagram) are based and tied-in at the end by an equation with the official stationing. This stationing was established in 1933, eliminating the original Sproul stationing, by beginning at the southern end of a general south to north route or at the west end of a general west to east route with 0+00 and carrying this stationing to a county line, where 0+00 was again used for the continuation of the route in the adjoining county. Where a previous construction survey adjoins or ends at the point of beginning or end of the new survey, an angular tie-in and the stationing equation should be shown.

1–34 If there be more than one traverse line run in the field, the stationing should be carried continuously independent of the other, and an equality made where the new survey crosses, but no equality should be made except at the ends of the new survey where it intersects with the previous line.

1–35 The soil investigation and the development of the soil profile will be conducted by the district organization under the supervision of the district soils engineer. If it is agreed that test borings and a soil profile should be made, it should be done as soon as the agreed center line is established and referenced and the grade line approximately determined. The district soils engineer shall instruct the persons designated by the district engineer to carry on this work, and forward the necessary samples to the Laboratory for test and classification. Upon receipt of the test results from the Laboratory, he will instruct and supervise the drafting of the soil profile. Sufficient copies of the soil profile must be available to all interested parties when making the second field inspection.

1–36 All horizontal and vertical measurements shall be in feet and decimals of a foot.

1–37 Stations are at one hundred (100) foot intervals, and intermediate points shall be designated by the back station plus the distance to the point in question. Example: (Station 148+62).

1–38 All side measurements to a tangent line are assumed to be at right angles unless an angle is shown. All measurements from the center line on a curve are assumed to be on radial lines.

1–39 Bench mark elevations shall be established to the nearest one hundredth (0.01) of a foot and the target shall be used on the level rod. The minimum recommended distance between bench marks is 1,000 feet.

1–40 A hundred (100) foot steel tape shall be used in establishing stations on the center line, in the measurement and setting of curve and reference points, and in all construction stake-outs. A steel tape shall be used in referencing hubs at P.I., P.C., P.T., P.O.T., and P.O.C. and similar important points with the utmost care. A steel tape shall be used in setting stakes for bridges and for other ac-

curate work and in obtaining final measurements of completed work. A metallic tape may be used for obtaining cross-sections and topography.

1–41 Special care must be used when chaining to see that the chain is horizontal and that sufficient "breaks" are made for this purpose. Should the terrain be too steep to permit measuring a required distance horizontally or on a level plane, it becomes necessary to set intermediate chaining points on the slope to attain correct distance. This is referred to as "breakchaining". A hand level may be used to aid in leveling the tape. Extreme caution must be exercised in this procedure to insure the correct horizontal distance is recorded. Where exact distances are required, a vertical angle taken with a transit and a slope distance taken with a steel tape may be used in order to compute the horizontal distance.

1–42 Of the several types of surveys used by the Department, each have their particular purpose as follows:

(a) Chain Surveys: Are used for the preparation of straight line diagram drawings, and are made by surface chaining along the center line of the present road, and all measurements and topography taken from this line. No curves or elevations are required.

(b) Low Cost Construction Surveys: Are generally used for Department Force Work, where no payment of final quantities are involved. This type of survey is a simplification of a preliminary survey with work and refinements not necessary for the project eliminated.

(c) Reconnaissance Surveys: As most commonly used is a field study of terrain to establish the general alignment for the location of a new road.

(d) Traverse Surveys: Are used to secure needed information, supplementing and generally in connection with either a reconnaissance or a preliminary survey. It consists of an angle line from which topography and elevations are taken. The angle line must be referenced to the highway center line by angles and a stational plus.

(e) Preliminary Surveys: Are made to secure complete and accurate data necessary for the preparation of drawings for the construction of a new highway and structures.

(f) Bridge Site Surveys: Are used when only a bridge and approaches are approved for construction, or as a separate survey in connection with a preliminary survey when a large or complicated structure is involved.

(g) Construction Surveys: Are used to re-establish the center line and provide the contractor with stakes from which he can determine the location and elevation for the construction of the new highway and structures.

(h) Borrow Pit Surveys: Are used to determine the amount of material removed from a certain location, for use in the new improvement.

(i) Final Surveys: Are used to determine payable quantities for certain items of the construction.

(j) Right of Way Surveys: Are used to determine the area of land condemned or for accurately locating the right of way lines in the field.

(k) Geodetic Surveys: Are used to establish basic triangulation and traverse monuments and bench marks. Are used further to establish horizontal and vertical control for photogrammetric mapping.

(l) Aerial Surveys: The production of map data by photogrammetric methods.

Form 4192 9-64
COMMONWEALTH OF PENNSYLVANIA
Department of Highways
Legal

WAIVER OF 10 - DAY NOTICE

County

L. R. Section

Owner (s)
Occupant (s)

of property io _____ City, Towoship, Borough

known as _____

hereby waive (s) the ten (10) days' ootice required in Article IV, Section 409, of Act No. 6, Special Sessioos, dated Juoe 22, 1964, and grant (s) to the Department of Highways, Commonwealth of Pennsylvania, its employes or agents the right to enter upon said property to make necessary studies, surveys, tests, soundings and/or appraisals for the constructioo, relocatioo and/or improvement of the above higbway.

_____
Date

INDIVIDUAL OR PARTNERSHIP

Witness _____ _____

Witness _____ _____

Witness _____ _____

Witness _____ _____

CORP., ASSOC., CLUB, ETC.

Attest:

_____
Corporatioo, Association, Club, etc.

_____
Secretary

By _____
Presideot

(SEAL)

Form 383 7-64

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF HIGHWAYS

NOTICE OF INTENT TO ENTER

You ore hereby notified, pursuont to Article IV, section 409, of Act No. 6, Speciol Session, doted June 22, 1964, thot in order to moke studies, surveys, tests, soundings ond / or opproisols it will be necessory for employees ond / or ogents of the Deportment of Highwoys, Commonweolth of Pennsylvonio, to enter your property on or obout

The employees ond / or ogents of the Deportment who will enter your property hove been cautioned to do their work expeditiously, courteously ond with os little interruption to your use of the premises os possible. We trust thot you will cooperote os fully with them.

Very truly yours,

District Engineer

CHAPTER TWO

ORGANIZATION OF CORPS

2–1 Corps for ordinary highway surveys shall consist of five (5) men; a chief-of-party in charge, an instrumentman, a rodman, a head chainman, and a rear chainman.

2–2 The chief-of-party shall be held responsible for the activities, actions, and remarks of his men in the field. He shall instruct them in the proper performance of their duties. He shall see that they cultivate the habit of doing the field work quickly, as well as accurately. He shall direct the attention of his superiors to individuals who have extraordinary ability and diligence, as well as to those who are not responsive to instructions or show little aptitude for survey work. Any man who is guilty of negligence, disobedience or gross misconduct shall be sent to the district office with a recommendation for disciplinary action.

2–3 Each man shall be trained to perform his own duties and those of his immediate superior. Instrumentmen must be able to use, adjust, and care for a transit, a level, and other surveying equipment, as well as taught to keep notes and take charge of the party during the absence of the chief-of-party. Rodmen must be able to chain, use a lock level and establish a foresight, as well as being taught to use, adjust, and take care of a transit, a level, or other surveying equipment. Chainmen must be able to chain properly, as well as being taught the duties of a rodman. Members of the party should occasionally alternate in the various kinds of service involved in the field work. This procedure is essential so that a corps may be able to operate during the absence of individual members, and to provide the Department with qualified men for promotion as vacancies occur.

2–4 The chief-of-party will be held responsible for coordinating the work of each individual to eliminate lost motion and unnecessary delays in order to achieve maximum efficiency. Where there will be an unusual amount of brush work, and such work will retard progress, an additional man or two, as required, may be obtained from the nearest maintenance superintendent to assist in clearing for the lines and sections. The use of these additional men must be justified on an economic basis. The experience and the ability of the individual members will control the assignment of tasks; but under average conditions, the division of work outlined in the following paragraphs has proven satisfactory.

2–5 The time required in the field for survey corps shall be the number of hours per day and days per week as designated by the Secretary of Highways, which will be actual working time on the job and will not include time consumed in going to and from work or checking notes.

2–6 Light rains or snow storms or snow on the ground will not be accepted as an excuse for not working. Where fog occurs along highways, presenting a hazard to the traveling public and the corps, other work shall be found until condition clears.

2–7 TRAVERSE SURVEY. It frequently becomes necessary to establish tentative lines before the ultimate location can be chosen. The chief-of-party, with all available information at hand, goes ahead, establishing the points, being governed by topography, maximum degrees of curvature, and rate of grade. He is followed by two men chaining the distances. The other men take profile and necessary cross-sections. In cases of this kind, it is often necessary for the chief-of-party to act as his own instrumentman, in addition to setting the points. A stadia survey is economical and efficient to establish trial lines, and to determine the contour and topography of the terrain to be traversed.

In making a stadia survey, the chief-of-party remains close to the instrumentman to record the notes. The rodman and the two chainmen each carry a level rod. The head chainman goes ahead, establishing the points to be occupied by the transit, and placing them at prominent breaks in the terrain and at locations where the transit can most adequately cover the area involved. The rear chainman gives the backsight and then comes forward on the back tangent, stopping at breaks in grade or other topographical features, such as streams, crossroads, etc., to give additional sights. The rodman gives sights for prominent changes in lateral slopes at the right and left of the line for cross sections.

2–8 PRELIMINARY SURVEYS. The corps shall be divided into two parties. The first consisting of the chief-of-party and two men, shall set and reference survey points, measure the angles and establish true bearing by observation on the sun, or polaris, as given in Chapter Eight of this Manual. The second, consisting of the instrumentman and one other member, shall establish bench marks and determine their elevations.

A full five-man party shall be used to stake the line. Permanent or fixed backsights or foresights shall be used whenever available. One man is delegated to give backsights and another to give foresights. Stakes are distributed along the line by the personnel bus, when the line is close to an existing road; or by the man giving the sight ahead, or they may be carried by the rear chainman who periodically gives the head chainman a half dozen or more. Stakes are not marked until the station is called by the rear chainman. In sparsely settled sections, topography can be located at the same time as the line; while the head chainman marks and drives a stake, the rear chainman and another man locate the topography. The head chainman assists whenever it is necessary to measure more than one chain length. In urban or suburban sections where traffic is heavy and there is considerable topography to be located, it is advisable to use the entire corps to locate topography after the line is staked.

In taking cross-sections, two men should be used as rodmen to increase the speed of the operation. The chief-of-party keeps notes, the instrumentman operates the level, one man calls offset distances, and each rodman stops at breaks where elevations are required. As soon as one rodman has completed his side of the road, he proceeds to the next station and locates the center line and stands ready for the first reading. The men assigned as rodmen should be changed frequently to increase efficiency.

Care should be observed in taking cross-sections, not to reverse left and right in the notes. This can be avoided by the member keeping the notes, always facing the direction in which the stations are increasing. It is good practice to make this a general rule in recording all notes where left and right sides are involved.

2–9 CONSTRUCTION SURVEYS. The instrumentman and two men chaining establish the line and one man with the help of the chief-of-party marks and distributes the stakes; the full corps shall be used to place and measure slope and offset stakes. After construction stakes are placed, the corps is divided; two men with a level determine and compute stake elevations; the remaining three men stake bridges, borrow pits, place radius points, and reference points where references have been destroyed or will be destroyed by the new construction.

2–10 FINAL SURVEYS. Where it is necessary to retrace the line, the full corps shall be used; two men chaining and one man painting stations. The full corps shall be utilized in taking the final topography and the final cross-sections. In taking cross-sections, one man is utilized to call measurements and two men are assigned as rodmen to increase the speed of operation—the chief-of-party designating where sections should be taken and recording the final sections and ties to old ground beyond the limits of construction.

When the topography and sections have been completed, two men shall be assigned to flat chain the road along the construction survey line. The remaining three men to make the additional chain survey required for the revision of the straight line diagrams and placing permanent station markers.

The full corps shall be used in taking final cross-sections of borrow pits, channel changes, etc.

2–11 GEODETIC SURVEYS. It may be necessary, from time to time, for survey corps to assist in the establishment of horizontal and vertical control for photogrammetric mapping. Work of this type will be under the supervision and direction of Central Office personnel qualified in this type of surveys and the particular equipment needed.

Each district shall make every effort to cooperate to the fullest extent since the control as established will be utilized for mapping on district projects. The mapping, when completed, will be forwarded to the districts for use in location and design.

2–12 REMARKS. In general, the corps shall be organized along these lines. However, local conditions, the time element, and magnitude of the work may make it advisable to change the procedure to secure maximum efficiency and economy.

CHAPTER THREE

CLASSIFICATION OF HIGHWAYS (DESIGN CRITERIA)

Note: The following applies mainly to design but is placed in the Survey Manual for your information.

3–1 When a preliminary survey is assigned to the District Chief-of-Surveys, one of his first duties will be to obtain the classification of the highway specified for the survey, inasmuch as the width, maximum grade, maximum degree of curvature and the minimum sight distance are dependent upon the classification determined for the particular project.

3–2 In the preparation of the following data it must be understood that special conditions encountered on individual projects could not be included. This data is subject to revision by the Central Office.

3–3 DESIGN SPEED & WIDTH OF PAVEMENT

Class of Highway		*Width of Pavement for Moving Traffic*	
Daily Average of Yeary Traffic	Design Speed	Paved traffic lanes between shoulders or paved parking lanes	Paved traffic lanes between raised curbs
Interstate All Traffic	70 (1)	4 or more 12 Ft. divided	4 or more 12 Ft. divided 3 Ft. offset from barrier curbs
Class 1 5000 and over	70 (1)	4 or more 12 Ft. divided	4 or more 12 Ft. divided 2 Ft. offset from barrier curb right—1 Ft. offset from barrier curb left in relation to direction of traffic
Class 2 1500 to 5000	60 (1)	2—12 Ft. lanes	2—14 Ft. lanes
Class 3 800 to 1500	60 (1)	22 Ft.	2—12 Ft. lanes
Class 4 200 to 800	50	20 Ft.	2—12 Ft. lanes
Class 5 0 to 200	40	18 Ft. (2)	

Notes:

(1) Topography and/or urban conditions may warrant design speeds of 50 or 60 miles per hour in specific locations.

(2) A 14-foot surfaced width for township and service roads may be provided which serves only one property.

3-4 ALIGNMENT.

(a) The combination of maximum curvature and grade shall be avoided on all classes of highways. Due consideration must be given to the ultimate necessity of by-passing congested built-up areas, especially those on Interstate, Class 1 and Class 2 Highways. The degree of curvature in all cases will be held as low as possible.

(b) Avoid sharp curves at the bottom or top of steep grades. Avoid beginning or ending a curve at or immediately beyond a summit of grade.

(c) Avoid broken-back curves but where compound curves are necessary the difference in radii shall be kept to a minimum.

3-5 GRADES.

(a) Grades on all highways will be held to or below the maximum designated on the chart below for the class of highway concerned. Justification will be required whenever these maximums are exceeded.

(b) **MAXIMUM GRADES UNDER NORMAL CONDITIONS.**

Class of Highway	Maximum Grade
Interstate	3% (1)(2)
1	3% (1)(2)
2	4% (2)
3	4% (2)
4	5% (2)
5	9% (3)

Notes:

(1) Adjust for descending grades steeper by 1%.

(2) Gradients 2% steeper may be provided in rugged terrain.

(3) Where traffic is less than 100 vehicles per day grades may exceed 9%.

3-6 SIGHT DISTANCE.

(a) Stopping sight distance is estimated to be the distance required for a vehicle to stop without hitting a stationary object ahead of it.

(b) Passing sight distance is estimated to be the distance required for a vehicle to safely pass a vehicle being overtaken.

(c) It is recognized that it would not be economical to provide safe passing sight distance at all points on a highway, but it is desirable to provide safe passing sight distance at frequent intervals.

(d) Please note that both sight distances in the chart below are minimum and should be exceeded where practicable. However, we are not justified in going to considerable expense to extend the length of stopping sight distances, which might encourage traffic to use them for passing.

(e) **MINIMUM SIGHT DISTANCE (HORIZONTAL AND VERTICAL).**

Class of Highway	Passing	Stopping
Interstate	—	600 Feet
1	(1)	600 Feet
2	2100 Feet	475 Feet
3	2100 Feet	475 Feet
4	1700 Feet	350 Feet
5	1300 Feet (2)	275 Feet (2)

Notes:

(1) When only two lanes are to be constructed initially—provide for passing distance.

(2) Where traffic in mountainous terrain is less than 100 vehicles per day, sight distance may be adjusted as required if grades exceed 9%.

3–7 MINIMUM VERTICAL CLEARANCE.

The minimum vertical clearance for structures over:

Defense Routed Highways	–16′ 6″
Other Highways	–14′ 6″
Electrified Railroads	–23′ 6″
Other Railroads	–22′ 0″

3–8 MINIMUM WIDTH OF SHOULDERS.

Class of Highway	Without Raised Curb	With Raised Curb (Measured from back of curb)
Interstate	10 Ft. cut section 12 Ft. fill section (10 Ft. paved)(1)(2)	Special Design
Class 1	10 Ft. cut section 12 Ft. fill section (10 Ft. paved)(1)(2)	3 Ft. cut section 4 Ft. fill section
Class 2	8 Ft. cut section 10 Ft. fill section	3 Ft. cut section 4 Ft. fill section
Class 3	6 Ft. cut section 8 Ft. fill section	3 Ft. cut section 4 Ft. fill section
Class 4	6 Ft. cut section 8 Ft. fill section	3 Ft. cut section 4 Ft. fill section
Class 5	6 Ft. cut section 8 Ft. fill section (3)	3 Ft. cut section 4 Ft. fill section

Notes:

(1) Median Shoulder: 8 feet wide (4 feet stabilized).

(2) Paved Shoulders: 10 feet wide where approved by Chief Engineer. Use 12-foot shoulders in excavation, when no swale is used.

(3) In mountainous terrain where traffic is less than 100 vehicles per day, shoulders may be reduced to 3 feet.

TABLE 3–1

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF HIGHWAYS
SUPERELEVATION CONTROLS
MINIMUM SPIRAL LENGTH, AND WIDENING

HORIZONTAL CURVES SHALL BE SUPERELEVATED ON STRAIGHT SLOPES FROM EDGE TO EDGE OF PAVEMENT AT THE TABULATED RATES FOR THE CLASS OF HIGHWAYS.

· GRADE CONTROL ·

FOUR LANE PAVEMENT WITH PAVED OR UNPAVED DIVISOR AREA : HOLD NORMAL GRADE ON EDGE OF PAVEMENT ADJACENT TO DIVISOR AREA. APPLY SUPERELEVATION DOWNWARD AND TRANSVERSELY THEREFROM FOR THE INNER LANE; UPWARD AND TRANSVERSELY THEREFROM FOR OUTER LANES.

ULTIMATE FOUR LANE PAVEMENT: SUPERELEVATION AND MINIMUM SPIRAL LENGTHS SHALL BE APPLIED IN ACCORDANCE WITH RATES TABULATED FOR INTERSTATE AND CLASS 1 HIGHWAYS.

TWO LANE PAVEMENT : HOLD GRADE AT THE NORMAL INSIDE EDGE OF PAVEMENT, PROFILE GRADE LESS NORMAL CROWN, AND APPLY SUPERELEVATION UPWARD AND TRANSVERSELY THEREFROM.

· CURVE CONTROL ·

SPIRAL CURVES SHALL BE APPLIED TO INTERSTATE, CLASS 1, AND CLASS 2 HIGHWAYS IN ACCORDANCE WITH PENNSYLVANIA DEPARTMENT OF HIGHWAYS STANDARD C-98 REVISED.

SPIRALLED CURVES : THE MINIMUM LENGTH OF A SPIRAL FOR THE DEGREE OF CURVE AND CLASS OF HIGHWAY SHALL BE AS INDICATED IN THE TABULATION.

SUPERELEVATION SHALL BE APPLIED BY REMOVING THE ADVERSE CROWN THROUGH THE TANGENT RUNOUT DISTANCE AND SUPERELEVATED AT THE NORMAL CROWN SLOPE AT THE T.S. TOTAL SUPERELEVATION SHALL BE ATTAINED ALONG THE LENGTH OF SPIRAL AND HELD FROM THE S.C. TO THE C.S.

NON-SPIRALLED, NON-WIDENED CURVES : SUPERELEVATION SHALL BE APPLIED BY USING THE RATE OF SUPERELEVATION AND THE TANGENT RUNOUT DISTANCES AS TABULATED FOR THE DEGREE OF CURVE. TOTAL SUPERELEVATION SHALL BE HELD FROM P.C. TO THE P.T.

NON-SPIRALLED, WIDENED CURVE : SUPERELEVATION SHALL BE APPLIED BY USING THE RATE OF SUPERELEVATION AND THE LENGTH OF RUNOFF DISTANCE AS TABULATED FOR THE DEGREE OF CURVE. CURVE WIDENING SHALL BE PLACED ON THE INSIDE EDGE OF CURVE AND SHALL BE ATTAINED IN A DISTANCE EQUIVALENT TO TWO-THIRDS ($^2/_3$) OF THE LENGTH OF RUNOFF, TO THE NEAREST FIVE (5') FEET, AS TABULATED FOR THE DEGREE OF CURVE TOTAL SUPERELEVATION AND FULL EXTRA WIDTH SHALL BE REACHED AT A POINT BEYOND THE P.C. AT A DISTANCE EQUIVALENT TO ONE-THIRD ($^1/_3$) OF THE LENGTH OF RUNOFF AS TABULATED FOR THE DEGREE OF CURVE. THE SAME PROCEDURE SHALL BE FOLLOWED AT THE P.T.

APPROVED NOVEMBER 5th, 1964

DIRECTOR OF HIGHWAY DESIGN

APPROVED NOVEMBER 5th, 1964

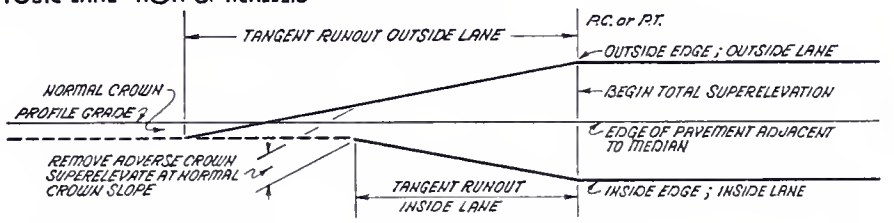
DEPUTY SECRETARY AND CHIEF ENGINEER

SHEET ONE OF FOUR

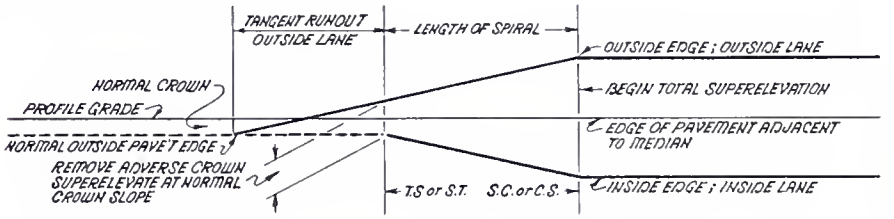
C 97

INTERSTATE, CLASS 1, AND ULTIMATE CLASS 1*
PROFILES SHOWING METHOD OF ATTAINING SUPERELEVATION

• FOUR LANE - NON SPIRALLED •


TANGENT RUNOUT OUTSIDE LANE
P.C. or P.T.
OUTSIDE EDGE ; OUTSIDE LANE
NORMAL CROWN
PROFILE GRADE
BEGIN TOTAL SUPERELEVATION
℄ EDGE OF PAVEMENT ADJACENT TO MEDIAN
REMOVE ADVERSE CROWN SUPERELEVATE AT NORMAL CROWN SLOPE
TANGENT RUNOUT INSIDE LANE
℄ INSIDE EDGE ; INSIDE LANE

• FOUR LANE SPIRALLED •


TANGENT RUNOUT OUTSIDE LANE
LENGTH OF SPIRAL
OUTSIDE EDGE ; OUTSIDE LANE
NORMAL CROWN
PROFILE GRADE
BEGIN TOTAL SUPERELEVATION
NORMAL OUTSIDE PAVET EDGE
℄ EDGE OF PAVEMENT ADJACENT TO MEDIAN
REMOVE ADVERSE CROWN SUPERELEVATE AT NORMAL CROWN SLOPE
T.S or S.T.
S.C. or C.S.
℄ INSIDE EDGE ; INSIDE LANE

SUPERELEVATION AND MINIMUM SPIRAL LENGTHS								
DEGREE OF CURVE	RIGID TYPE PAVEMENTS				FLEXIBLE TYPE PAVEMENTS			
	RATE OF S.E. PER FT. OF WIDTH	SPIRAL LENGTH	TANGENT RUNOUT		RATE OF S.E. PER FT. OF WIDTH	SPIRAL LENGTH	TANGENT RUNOUT	
			INNER ROADWAY	OUTER ROADWAY			INNER ROADWAY	OUTER ROADWAY
0°15′	⊕			100	1/4			200
0°30′	3/16"		30	130	1/4			200
0°45′	1/4"		55	155	1/4			200
1°00′	5/16"		80	180	5/16		30	230
1°15′	7/16"		130	230	7/16		80	280
1°30′	1/2"		155	255	1/2		100	300
1°45′	9/16"		180	280	9/16		130	330
2°00′	11/16"	250		100	11/16	200		200
2°15′	3/4"	250		100	3/4	200		200
2°30′	13/16"	300		100	13/16	250		200
2°45′	7/8"	300		100	7/8	250		200
3°00′	15/16"	350		100	15/16	300		200
3°15′	1"	350		100	1"	300		200
3°30′	1"	350		100	1"	300		200

NOTE – THE VALUES SHOWN ARE FOR 70 M.P.H. DESIGN SPEED. WHEN REQUIRED THESE MAY BE ADJUSTED TO COMPLY WITH OTHER APPROVED DESIGN SPEEDS.

* WHEN ONLY TWO LANES ARE TO BE BUILT INITIALLY.

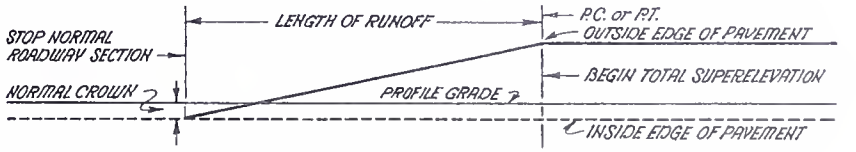
⊕ HOLD NORMAL SLOPES INSIDE ROADWAY; USE 1/8" S.E. ON OUTSIDE ROADWAY.

SHEET TWO OF FOUR

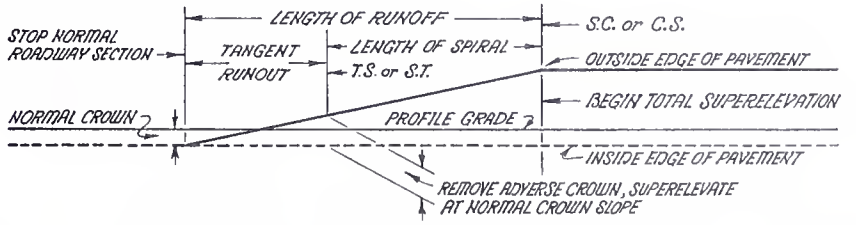
C 97

CLASS 2 *and* CLASS 3
PROFILES SHOWING METHOD OF ATTAINING SUPERELEVATION

• TWO LANE - NON SPIRALLED - NON WIDENED •



• TWO LANE - SPIRALLED •



SUPERELEVATION AND MINIMUM SPIRAL LENGTHS

DEGREE OF CURVE	RATE OF S.E. PER FT. OF WIDTH	RIGID TYPE PAVEMENTS			FLEXIBLE TYPE PAVEMENTS		
		SPIRAL LENGTH	22 OR 24 FT. PAVEMENTS		SPIRAL LENGTH	22 OR 24 FT. PAVEMENTS	
			LENGTH OF RUNOFF	TANGENT RUNOUT		LENGTH OF RUNOFF	TANGENT RUNOUT
0°15′	⊕		40			70	
0°30′	⊕		40			70	
0°45′	⊕		40			70	
1°00′	1/4"		70			70	
1°30′	7/16"		120			120	
2°00′	9/16"	150	190	40	150	220	70
2°30′	11/16"	150	190	40	150	220	70
3°00′	13/16"	200	240	40	150	220	70
3°30′	7/8"	200	240	40	200	270	70
4°00′	15/16"	250	290	40	200	270	70
4°30′	1"	250	290	40	200	270	70
5°00′	1"	250	290	40	250	320	70
6°00′	1"	250	290	40	250	320	70
6°15′ * and over	1"	250	290	40	250	320	70

NOTE - THE VALUES SHOWN ARE FOR 60 M.P.H. DESIGN SPEED. WHEN REQUIRED THESE VALUES MAY BE ADJUSTED TO COMPLY WITH OTHER APPROVED DESIGN SPEEDS.

⊕ REMOVE ADVERSE CROWN, SUPERELEVATE AT NORMAL CROWN SLOPE.

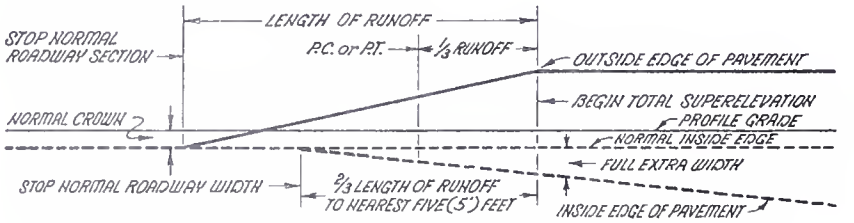
* WIDEN CLASS 3 PAVEMENT TO 24 FEET, TRANSITION WIDENING WITHIN LENGTH OF SPIRAL.

SHEET THREE OF FOUR

C 97

CLASS 4 and CLASS 5
PROFILE SHOWING METHOD OF ATTAINING SUPERELEVATION & WIDENING

• TWO LANE - NON SPIRALLED - WIDENED •



• TWO LANE - NON SPIRALLED - NON WIDENED • : USE CLASS 2 METHOD OF ATTAINING SUPERELEVATION

SUPERELEVATION CONTROLS AND WIDENING

DEGREE OF CURVE	RATE OF S.E. PER FT. OF WIDTH	CLASS 4		RATE OF S.E. PER FT. OF WIDTH	CLASS 5	
		LENGTH OF RUNOFF	TOTAL WIDTH		LENGTH OF RUNOFF	TOTAL WIDTH
0°15′	⊕	60	20	⊕	45	18
1°00′	1/4"	60	20	1/4"	45	18
1°30′	5/16"	75	20	1/4"	45	18
2°00′	7/16"	105	20	5/16"	55	18
2°30′	1/2"	120	20	3/8"	65	18
3°00′	5/8"	150	20	7/16"	80	18
3°30′	11/16"	165	20	1/2"	90	18
4°00′	3/4"	180	20	9/16"	100	18
4°30′	13/16"	195	20	9/16"	100	18
5°00′	7/8"	230	22	5/8"	110	18
5°30′	7/8"	230	22	11/16"	120	18
6°00′	15/16"	245	22	3/4"	150	20
6°30′	1"	260	22	3/4"	150	20
7°00′	1"	260	22	13/16"	165	20
7°30′	1"	260	22	13/16"	165	20
8°00′	1"	260	22	7/8"	190	22
8°30′	1"	260	22	15/16"	205	22
10°00′	1"	260	22	15/16"	205	22
10°30′	1"	290	24	1"	220	22
13°30′	1"	290	24	1"	220	22
14°00′ and over	1"	290	24	1"	240	24

⊕ REMOVE ADVERSE CROWN, SUPERELEVATE AT NORMAL CROWN SLOPE.

SHEET FOUR OF FOUR

C 97

CHAPTER FOUR

CHAIN SURVEYS

4–1 PURPOSE. A Chain survey is made to secure necessary information for the preparation of the official adoption notice of the road as a State Highway, and may be made at such other times as conditions warrant the rechaining of State Highway routes. The purpose of this type of survey is to determine the location and length of the route, type and width of the roadway pavement, location of overhead and undergrade bridges, railway grade crossings, and other structures within the highway right of way limits. In fact, the survey is in the nature of a complete inventory of the road and its physical features.

4–2 SURVEY CORPS. The survey corps for the chain survey shall consist of a chief-of-party, two chainmen and sufficient additional personnel to insure adherence to safety regulations. The survey corps shall work under the general supervision of the district chief-of-surveys.

4–3 PRELIMINARY DATA. Before the chain survey is started, the party chief shall be supplied with suitable maps showing the exact route or routes to be surveyed, the route numbers, beginning and ending of each route, or points mentioned in the Act of Assembly describing the route.

4–4 EQUIPMENT. The following equipment shall be issued to the party chief, who is held responsible for its care and return:

1. A supply of Field Notebooks, Form 428.
2. A supply of Bridge Records, Form 432.
3. A supply of Bridge Records, Form 433.
4. A supply of Railroad Crossing Forms, No. 421.
5. Pencils, 3H.
6. Two 100-foot steel tapes.
7. Two 50-foot metallic tapes.
8. Two hand axes.
9. Tacks.
10. 20-20 penny spikes.
11. Can of paint.
12. Two small paint brushes.
13. Box blue crayon.
14. Tape mending outfit.
15. 1″ x 2″ stakes.
16. One 30° x 60° triangle (6″ size).
17. One 100-foot steel chain with the first foot graduated in 10ths and 100ths, and each foot **only** marked thereafter.
18. One stake bag.
19. Two plumb bobs.
20. Box Yellow Crayon.
21. Caution Signs and Flags.
22. Sledge Hammer.
23. First Aid Kit.

4–5 PROCEDURE. 1. The center line of the highway shall be chained and recorded in a notebook. On curves, adjust the chain to the center line of the pavement by fixing its position at 25-foot intervals.

2. Surface chaining shall be used.

3. The stationing shall progress from west to east and from south to north. In all cases where a legislative route crosses a district line, the district engineers shall confer with one another to agree upon the direction of the Stationing.

4. Stationing shall not be carried continuously from one county into another, but the zero station shall be used at the county line for the continuation of a route into the adjacent county. Where the legislative description fixes the terminal point of the route at a borough or city line, the stationing shall begin or end in the borough or city at the intersection of another route. Where a route is described as traversing a portion of another route, the stationing shall not be continuous but shall be tied into the stations on the other route and the last station carried forward as the starting station for the chaining of the balance of the route.

5. The starting point shall be accurately referenced in the field. The most satisfactory reference is by means of three or four measurements from the fixed point to permanent objects. These measurements shall be horizontal, and less than 100 feet if possible and read to the nearest hundredth of a foot. The reference points shall be so spaced that the measurements from angles of approximately 90 degrees relative to each other. The reference points shall be clearly described and located by station plus and distance offset with respect to the center line of the roadway pavement.

6. Stationing shall be tied in to the stationing of other routes.

7. At approximately 1,000 foot intervals a station marker shall be set by painting on the roadway or by placing a stake marked with sunfast ink, paint, or crayon, as conditions warrant. The numerals shall be about 1½ inches in height and legible. The stationing shall be referenced to substantial objects at approximately half-mile intervals preferably at intersecting roads, if there are no other definite structures to which plusses have been taken. In referencing a point, it is unlawful to use a telephone or telegraph pole. Department personnel are not permitted to drive nails, tacks or spikes in these poles. A fence post is not considered a permanent object and shall not be used unless a more permanent object is not available.

8. The two chainmen proceed to surface chain along the center line of the highway, stopping to get plusses at all cross-drains, railroad crossings, structures, changes in type or width of pavement, etc. At each 100 foot station the head chainman leaves a spike or mark for the rear chainman, who moves forward as soon as this mark is established. The rear chainman calls the station he is about to leave and the head chainman calls the station he has just set. The chief-of-party records necessary topography and stationing with the help of the rear chainman as they both move forward on the chain. Meanwhile, the head chainman paints or marks stationing at necessary intervals, sets ties for control points, or assists with topography where necessary.

9. When required and directed, a stake shall be marked using sunfast ink, paint, or crayon with the correct straight line diagram station and placed at 1,000 foot intervals along the roadway. If conditions warrant, painted stations may be used

on hard road surfaces or on vertical face of curbs instead of stakes. The markings and stakes will be utilized by maintenance forces in erecting standard metal station markers.

4–6 SURVEY DATA. The survey corps shall secure the following data in making the chain survey:

1. Width and type of pavement, and width of graded roadway; plusses to be taken at changes in type and width.
2. All cross-drains by station number, showing kind, length, and size.
3. Plusses at all county, township, borough and city lines, and at each structure on the highway, such as railway tracks, bridges, or culverts and flashing signals.
4. Plusses at all center line intersections with township, county and State roads, and borough and city streets; intersecting roads to be identified by legislative route number and local name, and the approximate distance to the nearest town indicated. Ownership of intersecting road to be recorded, such as township or county road.
5. Names of all villages through which the route passes, and all control points mentioned in the act.
6. Name of borough and city streets, or other well-known roads traversed by the route.
7. Plusses to all public buildings.

4–7 CULVERTS AND BRIDGES. In securing data pertaining to culverts, bridges and overhead and underpass crossings, full details to completely fill out Forms 432 and 433 must be recorded in the notebook. In addition to sketches of the plan and elevation views, the following information shall be recorded:

1. Name of stream or branch of stream.
2. Direction of flow.
3. Number of spans and length of each span in the clear with widths of piers, if any, at bridge seat and at stream bed. (Clear span: right angle span between abutments and length of span on center line of roadway, measured accurately from face of top of abutment to face of top of abutment or pier. Measure span of arches at the spring line for both right angle span and span on center line of roadway).
4. Clear width between roadway curbs or wheel guards.
5. Clear width between parapets, girders, trusses or hand rails.
6. Width of sidewalks.
7. Type of superstructure, floor, stringers, etc., and general condition of each.
8. Type of substructure, including abutments, piers, wings, etc., and general condition of each.
9. Clear height or underclearance from roadway, railroad rails or bed of stream to underclearance of floor beams or girders.
10. Determine and record if bridge or culvert is the responsibility of the State, the county, the township, the borough, the city, or privately owned and maintained, and by whom. If possible, record when and by whom constructed (State, county, township, utility, private).

4–8 GRADE CROSSINGS. Locate and record by stational plusses all railroad, railway, and industrial tracks along or crossing the roadway. Note whether main line, branch line, or siding, giving the name of the company or owner and record the approximate angle to the roadway and condition of crossings, the clear sight views taken from a point one hundred (100) feet each side of the crossing, and state whether protection is provided and type of signs, signals, or other devices.

Obtain railroad crossing numbers located on railroad warning (crossbuck) signs near the grade crossing. This is a number established by the railroad company that indentifies and describes the crossing.

4–9 SEPARATION STRUCTURES. In the case of overhead (highway above railroad) or underpass (highway below railroad) crossing, full details of the structure shall be recorded as outlined for bridges, and such additional information obtained to permit compiling Form 421, Steam Railroad Crossing Report, for all such structures whether steam railroad, electric railway, or industrial railway.

4–10 SURVEY NOTES. The value of the survey rests not only on the accuracy with which it is performed, but also on the accuracy, legibility, and completeness of the notes recorded in the survey notebook.

A separate notebook shall be used for each route, and the identification table on the inside of the front cover shall be filled in at the time the survey is started, showing the district engineer's name and address, route number, date of starting, and the names and pay roll titles of the members of the survey corps. The balance of the information on this page shall be inserted immediately upon completion of the survey and prior to submitting the book to the district office. Pages 1 and 2 of the survey notebook shall be used to give the following data:

Local name or designation of road being surveyed, station to station.
U. S. mail route R. D. number (name of Post Office), station to station.
School bus route (name of school district), station to station.
P.U.C. bus route (name of bus line), station to station.
Mine road (name of mining company), station to station.

Survey notes shall be kept in accordance with standard practice, reading from bottom to top of page. Notes shall not be crowded and shall be clear and legible.

CHAPTER FIVE

SURVEYS FOR LOW COST CONSTRUCTION

5–1 GENERAL. In general this type of survey will apply to work performed by Department forces, where no payment of final quantities are involved, and no additional land taken, or on projects where resurfacing and widening of the present road are contemplated, within the legal right-of-way.

Where the present legal right-of-way is of sufficient width to accommodate the new construction, the center line and profile along the proposed construction with typical cross-sections at driveways and intersecting roads or other controls, will be all that will be required. This type of survey anticipates light grading and the slope lines of cuts and fills not extending beyond the legal right-of-way. The center line and profile provide a means of establishing grades for the guidance of Department forces.

When heavier cuts and fills are necessary and the limits of slope fall outside the legal right-of-way or when a shift in alignment or relocation is deemed advisable, a survey of sufficient refinement should be made to obtain enough data for the preparation of right-of-way plans to secure the necessary width and the abandonment of that portion of the legal right-of-way no longer needed.

Low-cost roadway construction surveys should be made as simple and economical as possible, but with due regard to general principle of accuracy as outlined in Preliminary Surveys, Chapter Eight of this Manual.

In order to keep down the cost of the survey, use shall be made of existing construction plans on projects which cover proposed widening along improved highways. Tracings shall be made of these construction plans and blue prints of construction cross-sections shall be secured from the Central Office. Field inspection will have to be made to check topography, property lines, names of property owners, and public or private utilities, to determine if any changes have taken place since the preparation of the original construction drawings.

5–2 ALIGNMENT. The alignment of the existing roadway should be followed generally with such modifications which will tend to reduce hazards of alignment, sight distance and grade, and reduce costs of construction by shortening the distance or decreasing grading quantities.

In establishing the alignment, particular attention must be given to economical grading costs and as far as practical to locating the entire pavement surface on firm ground. Particular care must be used in fixing the center line on sections where the existing roadway is narrow in order to establish the line, so as to secure the best results with the least amount of grading; this being very essential on steep hillside locations.

The district engineer, one of his assistants, or a qualified superintendent should make a preliminary inspection of the roadway site, taking into consideration the legal right-of-way and determine the various control points as well as any modification or revisions in alignment or grade which is deemed advisable.

The district engineer shall be notified of the completion of this preliminary study, at which time he or one of his assistants will make an inspection of the proposed

alignment and, where necessary, have stakes set and adjusted to meet his approval. After the alignment stakes are set to the satisfaction of the engineer, the chief-of-party shall be instructed to make the survey.

A survey along the center line of the approved location shall be run by the survey party. Bearings should be determined, checked, and recorded for all tangents and long chords.

The beginning and end of the survey and all intermediate transit points, including P. I.'s, P. O. T.'s P. C.'s, should be referenced accurately so that the line may be re-established.

Offset stakes shall be set at the survey stations, including breaks in grade, and located so that they may be used for the construction.

Curves up to sixteen (16) degrees shall be staked on fifty (50) foot chords, over sixteen (16) degrees on twenty-five (25) foot chords or shorter as conditions warrant. For method of staking out of curve see Preliminary Surveys, Chapter Eight of this Manual.

5–3 TOPOGRAPHY. This work should be simplified as much as possible. Topography shall be recorded by stational plusses and offset distances from the survey center line. Pole lines and fences will be located on tangents by giving stational plusses and the offset distances to the poles or fence points nearest the ends of the tangent and at such intermediate points where there may be a break in the line of poles or fence. Intermediate poles in a straight line may be located by stational plusses only. On curves they shall be located by individual plusses and offset distances, and the kind and size recorded. Angles of connecting roads, driveways and property lines, may be determined by pocket compass and only sufficient topography shall be taken on these as may be affected by construction. The edges of the traveled roadway shall be located by offset distances from the center line at all stakes and intermediate breaks in line of the traveled-way. In heavy cuts and hillside sections the edge of ditch or bottom of cut and the top of embankment shall be located in the same manner as the traveled-way, this being done to more readily show the existing graded width of roadbed at such critical locations.

The fronts of buildings and appurtenances which are within fifty (50) feet, or more if necessary, of the center line, shall be located by plusses and offset distances. Correct names of all property owners should be secured and recorded. In built-up sections all structures, including all public utilities, such as storm and sanitary sewers, water and gas mains, electric conduits and poles, together with ownership of same, as well as curbs, sidewalks and building lines should be located and recorded.

In built-up sections all structures, including all public utilities, such as storm and sanitary sewers, water and gas mains, electric conduits and poles, together with ownership of same, as well as curbs, sidewalks and building lines should be located and recorded.

County, township, borough and other legal sub-division lines should be located definitely as to stational plusses and angle of intersection with the survey center line by pocket compass where practical, also all utilities such as railroad, railway, pipe lines, and pole lines shall be accurately located and recorded with the names and owners.

Complete data shall be secured for all culverts; the location, skew, size, length, and other important dimensions shall be carefully recorded for each.

Surveys for bridges should follow standard practice as outlined for Bridge Site Surveys, Chapter Ten of this Manual.

Where modifications or revisions of alignment are made which will require additional or new right-of-way, sufficient data must be secured to permit the satisfactory plotting or drawings for condemnation of the required property.

5–4 PROFILE. Where it is anticipated that the total width of the proposed work, including the top of slopes in cut sections and the bottom of slopes in fill sections, falls within the legal right-of-way it will not be necessary to take cross-sections. However, a profile should be run.

Bench marks shall be established in the standard manner to the nearest one-hundredth (0.01) of a foot. Profile readings to the nearest one-tenth (0.10) of a foot should be taken by means of a wye level for all center line points opposite stakes at stations and intermediate breaks. Readings shall be taken and recorded to the nearest one-hundredth (0.01) of a foot for tops of all offset stakes and nearest one-tenth (0.10) of a foot for ground elevations at stakes. Elevations shall be taken of flow lines of pipes and small culverts and profiles of the ground or stream line extended for a distance of at least fifty (50) feet beyond each end of the pipe or culvert. Profiles shall be taken at low points or other advisable locations in like manner, if no culvert exists at present. Profiles should be plotted to facilitate the establishment and the correct location of drainage structures and ditches.

At intersecting roadways and drives, profile elevations shall be taken for such distances as may be affected by construction.

At railroad and railway crossings, elevations and cross-sections shall be taken as outlined under "Preliminary Surveys," Chapter Eight of this Manual. Where a railroad or railway parallels the proposed alignment and within a distance that may be affected by the proposed construction, the tracks and structures shall be located and the roadway cross-sections extended or typical sections taken.

5–5 CROSS-SECTIONS. In cases where heavy grading is deemed advisable to reduce steep grades, to secure necessary width in heavy cuts or on hillsides, or on relocations, where it is required to load and haul a considerable amount of material, standard cross-sections must be taken and construction grades established.

CHAPTER SIX

RECONNAISSANCE SURVEYS

6–1 When anticipating the construction of a route, a field study or reconnaissance survey should first be made of the existing highway and the surrounding terrain to determine from an engineering standpoint the location which will best serve traffic, the population in that area, and the continuation of the highway at either end between definite major control points or termini for the particular portion of the roadway involved.

6–2 In preparation for a field study where the known conditions on the existing highway will not lend themselves readily to the type of highway consistent with the volume and character of the anticipated traffic, as outlined in the Department's "Classification of Highways," Chapter Three of this Manual, all existing data and information should be studied as an approach in considering a relocation. When alternate lines for relocating a highway are considered, the quickest and most economical method is by the combined use of aerial photographs and accurate photogrammetric contour maps. By the use of the latest advances in aerial surveying, ground reconnaissance can be largely eliminated. Alternate lines can be located and yardage estimates obtained. Drainage watersheds can be plotted for culvert and bridge design calculations. Bridge sites and approaches may be selected, preliminary grading studies made and other pertinent information obtained by which the alignment can be determined and the information given to the corps to start the preliminary survey. "General Highway Series County Maps," straight line diagrams and previous surveys, plans, and reports should be reviewed.

6–3 A reconnaissance survey, to be of real value in determining the ultimate location of a highway, requires careful study by the district engineer or competent members of the district staff. The three (3) following points must be considered individually and collectively to determine the ultimate location and design.

1. Select the design and requirements of the proposed highway in accordance with the needs of the traffic which will use the highway upon its completion. Very often when a complete traffic analysis is made of the contemplated improvement of a route between urban centers it will be found that with the final improvement the traffic will elect to use the reconstructed highway in lieu of alternate or adjacent roads. In some cases, adjacent routes, when ultimately reconstructed, will divert traffic from the project now under consideration and this factor should be considered in the design.
2. Establish control points a sufficient distance beyond the present proposed construction, to be reasonably sure that the ultimate alignment and grades can be established without destruction or abandonment of any of the present proposed construction. Where present conditions prohibit the coordination of the proposed construction with future developments, the proposed construction should be limited to the portion which is definitely on the ultimate alignment and grade, providing temporary connections to the present road.

3. The selection of the general location of the route between the proposed limits, conforming to the latest standards of design and requirements, shall take into consideration construction, maintenance, right-of-way cost, and safety in vehicle operation. All possible locations should be thoroughly investigated to insure that the alignment selected will best serve the traveling public. Where the route in question is primary for the use of the local traffic the present location should be given first consideration. Where the proposed project is on a through highway connecting large urban centers and where the present facilities adequately serve the local inhabitants the proposed location may favor the through traffic.

6–4 A heavily traveled road warrants greater refinements in grades, curvature and sight distance, with grade separations at railoads and intersecting highways, than would be considered economically advisable on a road with little travel. Certain natural conditions of the terrain and adjacent features have an important bearing upon the selection of a location, such as streams, flood areas, slide formations, swamps, excessive rock excavation, snow removal, exposure, mining operations, railroads, and excessive damages. Some of these conditions may be avoided by modifying the alignment. However, before a decision is made, the advisability of special construction in such cases as compared with avoiding the condition should be investigated and construction cost, property damage, and annual maintenance cost should be considered in each case.

6–5 Variation in topography throughout the Commonwealth justifies various methods being employed on a reconnaissance. If the relocation is over a flat or rolling country and there is little or no obstruction to the vision, the general location may be chosen on the reconnaissance. Where due to wooded or broken country it is not practical to determine a suitable location by reconnaissance, traverse surveys should be made only as required to secure the necessary information.

6–6 While traverse surveys may increase the engineering cost they are fully justified in rough terrain to determine the most practical location, and should be made as required in lieu of the possibility of making detailed surveys on impractical locations.

6–7 The information and data secured by the reconnaissance and traverse survey should be used in the preparation of Relocation Reports, Forms 468 or 468-B, and attached sketches, to give the Central Office a comprehensive report of field conditions. These reports shall also indicate whether previous relocation reports, surveys and drawings were made, and reasons for or against previously considered locations. Difference of opinion as to locations naturally occur, therefore the submission of these various studies and recommendations permits a more thorough knowledge of the conditions and enables the Central Office to make a more intelligent decision as to the most feasible location. The relocation report shall contain the district engineer's reasons for his recommendation and should be personally approved by him and forwarded to the Central Office.

6–8 Reconnaissance surveys may be made and charged to general engineering, however, traverse and detailed surveys should not be made until request for the Preliminary Engineering Authorization, Form 4200, is submitted and approved by the Central Office.

6–9 After the general location has been determined and approved, the chief-of-party should be taken over the proposed location and furnished with all available information and control points, in order that the preliminary survey may be made accurately and on the correct alignment.

CHAPTER SEVEN

TRAVERSE SURVEYS

7–1 A traverse survey is generally made to secure additional information to complete a reconnaissance; to secure sufficient information to prepare a plan of road to be abandoned as a State Highway, or to locate the old road in connection with a preliminary survey; to locate streams, railroads or other public utilities. The extent and refinements of the survey will depend upon the information desired. No more corps work should be performed than is necessary to secure the desired information. When it is not practical to determine a suitable location on the reconnaissance due to rough and wooded terrain, a traverse and/or stadia survey is practical and economical.

7–2 The traverse line shall be run and the P. I.'s referenced as for a preliminary survey. The line shall be marked so as to be easily located and the stakes on relocation should be placed on the center line. No curves should be run in unless instructed. Strips of red or white cloth can be used to locate the line through, and at beginning and end of woods, at fence lines and through broken country so as to be easily followed.

7–3 When running a traverse survey for the location of a railroad, old road or stream, it is necessary that the beginning, ending, and all crossings of the survey line be clearly indicated by stational plusses on both lines. Traverse surveys shall close within a maximum error of one (1) minute per mile and the total error shall be distributed among the angles of the traverse survey, so the error will not seriously affect the calculation.

7–4 Only topography which will influence the lines and grade should be taken. When a profile and/or typical sections are required, the elevation of the starting bench mark may be assumed if a known bench mark is not conveniently available. The work performed should be accurate and the notes kept neatly.

7–5 Particular attention must be given to high water elevations, drainage areas and present structures, so the cost of bridges and other drainage structures may be estimated with fair accuracy.

CHAPTER EIGHT

PRELIMINARY SURVEYS

8–1 After approval of the location has been received from the Central Office, the chief-of-party shall be taken over the proposed route and shown the general alignment and controls as established by the reconnaissance and/or the traverse survey. The center line established on the preliminary survey should be the construction center line with few, if any, changes made in the office. All controversial issues should have been decided before the survey started.

8–2 The notes of the preliminary survey must show the actual physical conditions as they are at the time the survey is made. Particular attention must be given to all details and structures, underneath, on the ground or overhead, which may in any way affect the location, construction or amount of damages. The notes must be complete and neatly entered in the notebooks.

8–3 Before starting the survey the chief-of-party should have obtained from his superior all the necessary information, such as the controls to be observed according to the "Classification of Highways," as outlined in Chapter Three, of this Manual, location of convenient U. S. C. & G. S. or Department bench marks, survey authorization number and other necessary data.

8–4 The preliminary survey proceeds in the following order:

1. Establish the center line throughout the project, determine stationing, and run in curves. At this time if there are any special "Bridge Site Surveys," necessary for large structures, they should be made to enable the Central Bridge Unit to start the design. Also, if certain locations require special designs, this work should be performed first and the data forwarded to the district office.
2. Establish bench marks and check levels throughout project.
3. Take topography.
4. Take cross-sections.
5. Have soil investigation made under direction of the district soils engineer, when specifically ordered by the district engineer.

(See Chapter Fifteen of this Manual for preparation of notebooks and symbols to be used.)

8–5 Center Line. The location of the center line requires great care and the best judgment, and the chief-of-party should not attempt to run a center line without first going over the ground carefully and establishing approximate P. I.'s, consideration being given to the grades and curvature controls, before his party starts work. Whenever possible the chief-of-party shall be accompanied by his superior on this preliminary work.

(A) On all highway projects carrying one thousand, five hundred (1500) vehicles or more daily, spiral transitions to horizontal curves shall be used on curves of two (2) degrees or more. The tables and computations

as given in the handbook "Transition Curves for Highway," published by the United States Department of Agriculture, shall be used for this purpose.

(B) The P. I.'s, P. C.'s, P. T.'s, P. O. T.'s, and any other reference points are to be established by utilizing large spikes, except in soft grounds, when hub stakes, properly tacked, may be used. Guard stakes should always be placed when hubs are used. All of these points are to be carefully and accurately referenced to at least three permanent objects beyond the limits of construction, by steel tape measurements to the nearest one-hundredth (0.01) of a foot, care being used to see that these three objects form a well-proportioned intersection. Otherwise these measurements, when utilized to re-establish the point, may be questionable if one of the references should be disturbed or destroyed.

(C) The center line shall be referenced by stakes set at right angles to the center line on tangents, at each station and half station. The same procedure shall be used on curves up to and including sixteen (16) degrees, except that center line offset stakes shall be placed on radial lines. When the curve is sharper than sixteen (16) degrees the center line shall be staked at twenty-five (25) foot or lesser, intervals. The distance from the center line to the offset stake shall be measured to the nearest one-tenth (0.1) of a foot and where practical, stakes should be placed on the same side of the center line.

(D) The line and profile shall be taken for at least five hundred (500) feet beyond each end of the work, or for a greater length if grade or alignment adjacent to either end are questionable, in order that the line and grade may be determined for future construction. This should be done in order to avoid "choking" the alignment or grade on later improvements and should be carefully checked by the district engineer or his assistants.

8–6 True Bearings. Observations shall be taken on Polaris, or on the sun, to determine the true bearing of a tangent, every three (3) to five (5) miles. On short surveys only one observation will be necessary, or the true bearing on a short survey may be obtained from data secured on an adjacent survey provided a true bearing was previously determined on the adjacent survey. A total error in Azimuth of a line should not exceed one (1) minute per mile, and this error shall be distributed among the angles so the calculations will not be affected. Bearings must tie in, and the observations should be reduced and true bearings worked for line before the notebooks are forwarded to the district office.

8–7 Bench Levels. While the line is being run, or shortly thereafter, an accurate set of bench levels must be established over the entire survey, starting from an established U. S. C. & G. S. bench mark or a bench mark previously established from such a U. S. C. & G. S. bench mark. When possible the bench levels shall tie in with the same system of elevations as started with. If sufficient time is available the bench levels should be checked back to the starting elevation, otherwise each bench mark shall be used as a turning point when the cross-sections are taken and an error of three-hundredths (0.03) of a foot between bench marks shall not be exceeded, nor shall this error be accumulative, and a tolerance of 0.05 D (where "D" is the distance in miles between bench marks) shall not be exceeded in bench or check levels. Bench marks shall be established at approxi-

mately one thousand (1000) foot intervals and located outside the area to be disturbed by the construction. They shall be substantial and well marked so as to be readily found by other field parties, and located by descriptions carefully recorded with sketches in the notes. The target may be used on the rod and read to the nearest one-hundredth (0.01) of a foot, when running or checking bench levels.

8–8 Curve Procedure. Curves from one (1) degree to sixteen (16) degrees, inclusive, shall be run using a fifty (50) foot chord length. Curves above sixteen (16) degrees to twenty-six (26) degrees shall be run using a twenty-five (25) foot chord length. Compensation for sub-chord length being made in both cases. However, a District Engineer, at his discretion, is granted the authority to utilize the actual arc method on curves from one (1) degree to twenty-six (26) degrees.

(A) **All** curves above twenty-six (26) degrees are to be run by means of the true arc method. An earlier practice of using the arc method with a chord radius on degrees of curvature over twenty-six (26) degrees is eliminated upon the publication of this survey manual. Computations on the arc method shall be in accordance with the "Manual on Highway Curves," as written by Ives and Kissam.

(B) All construction plans shall be conspicuously marked designating the curve method utilized on each individual project. Each curve data shall be marked "**chord**" or "**arc**" to insure clarity of method used.

(C) Spiral transition to horizontal curves will be used on curves of two (2) degrees or more on all highway projects carrying one thousand, five hundred (1500) vehicles or more daily.

(D) The curve data should be recorded on the left-hand page of notebook, opposite the P. I., and should include the following information:

Curve Data	*Deflections*	*Calculated True Bearing*	*Magnetic Bearing*
Azimuth angle 187° –1½′		N 56°37′30″ E	N 65°30′ E
Doubled angle 14°03′			
P. I. –633+16.83	P.C. –0°00′		
A –7°01′30″ Rt.	+ 50–0°25′15″		
D – 4°	633–1°25′15″		
T – 87.94′	+ 50–2°25′15″		
L –175.62′	634–3°25′15″		
P. C. – 632 + 28.89	+ 04.51–3°30′45″		
P. T. – 634 + 04.51		N 48°36′00″ E	N 57°30′ E

(E) At each P. I., or point of intersection, record the station and the reading of the angle, which angle should be turned clock-wise, vernier set at zero, reading recorded, the angle doubled, and again recorded. The deflection angle and direction (right or left) should be noted in the curve data. The magnetic bearing of the forward tangent should always be read and recorded.

(F) Careful consideration should be given to determine the best possible curve within economic limits, the degree of curvature, depending upon the character of the location, percent of grade and the amount of grading quantities involved. On main highways the sight distance required is

the principal consideration in determining the degree of curve. The curve radius required for minimum non-passing sight distance and passing sight distance can be determined from information furnished under Chapter Three of this Manual. The superelevation and widening of curves shall conform to the requirements of Department Standard.

(G) Short tangents between curves should be avoided, and if a simple surve will not suffice, then consideration should be given to a compound curve. When compounding curves, endeavor to secure two curves of approximately uniform curvature, avoiding the odd minutes.

8–9 Transition Curves. At moderate speeds the average driver can traverse a satisfactory short transition path within the limits of a vehicle lane but with increased speeds longer transitions are required. These can be traversed only by hazardous crowding or occupation of adjoining lanes. The increase in speeds at which vehicles are operated, the desire for increased speed with safety, and the mounting accident toll make it imperative that highways be constructed in such a manner that a driver, traveling at the safe speed for which the highway is designed, will not only find it possible to confine his vehicle to the occupied lane but will be encouraged to do so by transition curves and correct superelevation design.

(A) In urban areas the need for transition curves is comparatively small, as traffic controls, density of traffic, numerous intersections, changing roadway widths, pavement types, parked vehicles, pedestrians and other causes, tend to decrease speed and make frequent stops necessary.

(B) Outside urban areas traffic speeds tend to increase to a comfortable cruising speed according to the speed capacity and type of vehicle, traffic density and physical characteristics of the highway. The safe driving speed is seldom the maximum speed of the vehicle because it is not deemed economically advisable to construct highways at the present time for maximum speeds because of the personal factor and the cost to eliminate physical characteristics for safe driving at maximum speeds.

(C) The principal factor affecting the choice of a design speed is the character of the terrain, and the density and type of traffic which will use the new highway, and transition curves and superelevation should accordingly be selected to fit the design speed. The tables, computations and other data are too voluminous to include in this Manual but reference can be made to the handbook "Transition Curves for Highways" published by the United States Department of Agriculture, Public Roads Administration or other handbooks recognized as an authority by this Department.

8–10 Topography. Topography shall be taken from the established center line, or from a traverse line accurately tied into the established center line by angles and distances. When a traverse line is used to secure topography and cross-sections at a distance from the center line, such as a railroad or stream crossing the highway, it will be assumed that the measurements are at right angles to the traverse line at that point unless otherwise shown by a recorded angle. The traverse line must be run by a transit and the angles and distances accurately determined. Care must be used in taking topography and cross-sections near the intersection angles, otherwise when plotted the locations and elevations will not agree. It is recommended that baselines for streams, township roads, railroads, etc., that carry no straight line diagram stations be started left of center line and

stations increase from left to right, crossing the main center line with an arbitrary station of 10 + 0 rather than 0 + 0. This will eliminate minus stations in event of a minor office revision or line shift at a later date. The use of 0 + 0 should be eliminated at all cross baselines unless warranted by straight line stations.

(A) Political sub-division lines, railroad crossings, intersecting public highways, or other objects or conditions which may affect the design, construction or cost shall be located by instrument. All other topography shall be located by right angle distances from the established center line or traverse line unless it is deemed advisable to use an instrument.

(B) Locate all buildings, structures or conditions such as swamps, mines, quarries or rock ledges within one hundred (100) feet of the center line. When it is evident that certain objects or conditions outside this limit will be valuable for study in the design of the project, they shall be located.

(C) Locate all fence and property lines, both parallel to and at angles to the center line. The correct name and address of every property owner within or adjacent to the proposed right-of-way shall be secured. Initials or abbreviations of the first name must not be used. Notes such as "owner unknown" or W. R. Jones will not be accepted. The correct name and address should be recorded as "William R. Jones, R. D. No. 2, Lebanon, Pa." If the property is owned jointly by husband and wife both names shall be given, and when an estate, the name and address of the executor or executrix shall be secured. In locating buildings or structures, determine the length and depth, porches, offsets, type of construction, and size and depth of cellar. Poles with the initials of the owner, and pole number when given, shall be located and shown.

(D) Locate and show the following:

Trees, four (4) inches in diameter or over, bushes and hedges. (Give name and diameters.) Public roads, private drives, lanes or field entrances. In the case of Highway routes, show route number and distance, and name of nearest town. For other public roads show county or township and indicate name and distance to nearest town.

Walls, monuments (both public and private), near grave line at cemeteries, oil and gas lines, old milestones and signs.

United States, railroad or Department bench marks. Cross-drains, with their length, diameter and kind of pipe. In built-up communities, in addition to other details, it is necessary to locate and obtain the names of all streets and alleys traversing or adjacent to the survey; also all paved crossings and type of surface on the crossings, streets and alleys; all underground pipe, sanitary or storm sewers, gas and water mains, hydrants, private lines, conduits along or crossing the highway; manholes, inlets and valve boxes; paved gutters, curbs, and sidewalks, with type of construction.

Within the limits of construction all trees in an orchard must be located, giving the trunk diameters, condition and age, if possible, and the kind of trees, such as apple or peach orchard.

Locate the edges of the traveled road and the type.

At railroad crossings, show angle of crossing, and line and profile for at least five hundred (500) feet each side of the center line. Give the name of the railroad and branch line or siding, as the case may be, width

of right-of-way, and number of trains each way per day. Locate all railroad signals, switches, poles, and other physical appurtenances along the railroad adjacent to the highway. Locate all railroad signs of any description, and make a side sketch of sign and all information on such signs. Obtain crossing number located on warning (cross-buck) signs. All gullies or ravines by station plus, skew, and extent.

At all bridge or stream crossings, a separate sketch of the stream and adjacent topography shall be shown for at least five hundred (500) feet each side of the center line. (This does not refer to a stream which can be accommodated by the average size pipe. Good judgment will indicate when it is necessary to run a traverse line to secure the information.) The existing structure shall be shown by a sketch, giving the roadway clearance, span, clear height, type of structure, condition, depth, and name of stream and the direction of flow. Secure high water elevations and information as to the adequacy of the waterway of the present bridge, stating in the notebook from whom such information was secured and in what years the water reached its highest stages. In securing the high water elevation, the free flow elevation should be considered, and not one caused by ice or driftwood, unless that is the general condition, and then such elevations should be noted. For large bridges, the highest water elevations should be secured for at least two flood years, and source of information, whenever available, must be secured for all streams requiring bridges of one hundred (100) foot span or more. If roadway locations are subject to floods, show the limits, depth of flood waters at given stations, and any other conditions which may govern the grade line necessary for the protection of the roadway. (See Chapter Ten of this Manual for instructions on large structures.)

Indicate the limits of swamps, mines, coal or mineral deposits, boulders, brush, wooded areas, and local quarries.

When the survey leaves the present route, a traverse line shall be run on the old road and the topography taken, unless a recent survey will give the desired information. Information necessary to determine the grades of the present road shall be taken. An equation shall be recorded where the two lines meet.

If a railroad or stream parallels the survey and is within three hundred (300) feet of the center line, it shall be located either by a traverse line tied in with the center line or by sufficient offset distances from the center line at given stations.

The nature of the land (wooded, cultivated field, or similar characteristic) and the condition of the ground (earth, rocky, sandy, or swamp) should be noted.

8–11 Cross-Sections. If not previously done, bench marks must be checked as provided for previously under "Bench Levels," in this Chapter.

(A) An Engineer's level shall be used for all readings whenever possible, and all turns shall be read to the nearest one-hundredth (0.01) of a foot. Extreme care must be used to see that the cross-sections are taken at right angles to the center line on tangents, and on radius lines on curves. The offsets shall generally be recorded to the nearest one-tenth (0.1) of a foot and the rod read to the nearest one-tenth (0.1) of a foot.

However, in built-up communities or where adjacent construction is involved, such as curbs, railroads, connecting roadways or structures, the rod shall be read to the nearest one-hundredth (0.01) of a foot. If it is necessary to use a hand level to extend the section, such work shall be done with great care in order that the final sections will check with the preliminary sections beyond where the ground was disturbed. When elevations are taken below "high rod," a rule shall be used and care exercised to secure correct elevations. Balancing the rod along the body is not permitted.

(B) Cross-sections shall be taken at each station and each fifty (50) foot point on the center line and at breaks in the ground, either on the center line or on either side, which will affect the earthwork quantities. The alignment of side roads shall be referenced in relation to the center line and a profile and sufficient sections taken so the amount of cut or fill can readily be determined. The length of line on intersecting roads must be sufficient to permit the establishment of practical grades on these roads.

(C) All sections shall extend to the proposed right-of-way line, and beyond when the estimated cut or fill require longer sections.

(D) The elevations of all points or objects which might in any way affect the design, grade, or elevation of the proposed road or structures, shall be carefully determined and recorded.

(E) All large boulders within the proposed construction limits shall be located and the dimensions above ground given in order to determine the yardage.

(F) In crossing streams, short ravines, old and existing roadways, and similar conditions, take sections at the top and bottom of the bank on each side, so that a true profile of the center line can be reproduced and the earthwork correctly computed.

(G) The profile of streams shall be run for five hundred (500) feet minimum on each side of the center line, showing both stream bed and surface water elevation. In addition, where there is an existing structure in place, sections shall be taken at the end of the wings, and ten (10) and twenty-five (25) feet back of the ends of the wings. (See Chapter Ten of this Manual for instructions on large structures.)

(H) Elevations shall be given for the inlets, outlets, and present ground at center line of all existing pipes and culverts. Notations shall be made as to whether or not the existing pipe is of sufficient size during flood periods. This can be obtained by evidence on the ground or from local residents. A profile with one or more typical sections shall be taken for all gullies for at least one-hundred and fifty (150) feet on each side of the center lines. On small pipes show fifty (50) feet of drainage profile at each end of pipe.

(I) At railroad crossings, secure an elevation on top of each rail crossed on the center line, and similarly at each proposed shoulder line. Secure a profile of the top of rail for at least five hundred (500) feet each side of the center line. The readings shall be taken every fifty (50) feet to the nearest one-hundredth (0.01) of a foot. Where the railroad tracks are on a curve the profile should be taken on the low rail and sufficient profile of the high rail to ensure a correct grade and construction design.

(J) When buildings are near the limits of construction, an elevation should be given for the ground at the entrance, porch floor, and first floor of the structure; if a barn, on the floor of the barn, and when a lower floor is used for horses or cattle, an elevation on that floor. An elevation should be given for the top of foundation and the type of foundation, as stone, concrete, or other material. Note if structure has a cellar, or other foundation below the ground line, and the depth below the top of the foundation.

(K) All cross-sections, profiles, and other computations shall be figured and checked in the field by the corps, and noted by whom computed and checked. This work being performed each day so that when the survey is finished the computations will have been completed. The chief-of-party will be held responsible for this work and also, that the books are forwarded to the district office as requested.

8–12 CONVERGENCE OF MERIDIANS

First Method

The Angular Meridional Convergence = difference in Longitude X sin. of Latitude. (See page 65, Merriam & Brooks Handbook for Surveyors.)

Referring to page 253, table three of Merriman's Precise Surveying and Geodesy:

(a) Angular Meridional Convergence lat. 39°–43′ = $\dfrac{60 + 5280}{1429.10 \times 3.2801}$

X sin. 39°–43′ = 43.2 seconds per miles of Easting or Westing.

(b) Angular Meridional Convergence lat. 42°–00′ = $\dfrac{60 + 5280}{1380.90 \times 3.2801}$

X sin. 42°–00′ = 46.8 seconds per mile of Easting or Westing.

The average theoretical convergence of meridians for Pennsylvania = 45 seconds per mile of Easting or Westing.

8–13 Second Method

(a) The azimuth of the tangent to the parallel at latitude 39°–43′ = 89°–59′–16.8″.

(b) The azimuth of the tangent to the parallel at latitude 42°–00′ = 89°–59′–13.2″.

Note: The above azimuth refers to a point one mile Eastwardly from the point of beginning where the azimuth of the tangent is 90°.

(See page 116, table No. 9, Manual of Instructions for Survey of Public Lands, 1902)

(a)	(b)
90°–00′–00″	90°–00′–00″
89°–59′–16.8″	89°–59′–13.2″
0°–00′–43.2″	0°–00′–46.8″

The average theoretical convergence of meridians for Pennsylvania = $\dfrac{43.2 + 46.8}{2}$

=45.0 seconds per mile of Easting or Westing.

Note: When progressing eastwardly add 45.0″ to azimuth per mile of Easting. When progressing westardly substract 45.0″ from azimuth per mile of Westing.

An additional tolerance allowable for the personal equation = one minute, hence the maximum allowable variation per mile = one minute (personal equation) plus convergence of the meridians.

Note: The convergence of meridians varies from a maximum of 45 seconds when progressing east or west to zero when progressing due north or south.

Examples

Maximum allowable variation per mile between observations.

General Direction	Maximum Allowable Variation
East or West	1 minute 45 seconds
N 30°E, N 30°W, S 30°E, S 30°W	1 minute 22.5 seconds
North or South	1 minute 0.0 seconds

This variation should be absorbed in the ½ minute angles.

8–14 MERIDIAN BY OBSERVATION ON POLARIS AT ELONGATION

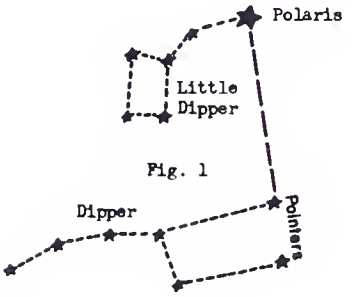


Fig. 1

Fig. 2

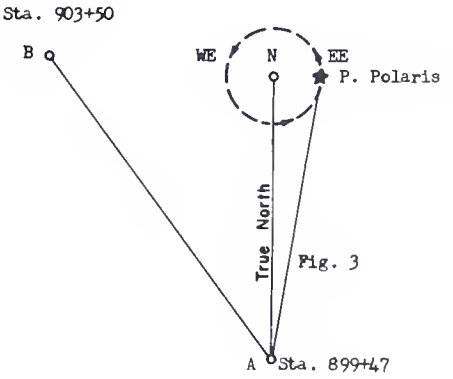


Fig. 3

Observations on Polaris or the sun to determine true bearings of survey centerlines should be made with an engineer's transit at the beginning of short surveys and every three to five miles on long surveys.

If the location where an observation is desired is in the center of an existing highway where the observer would be disturbed by traffic an offset line should be established that would eliminate this condition.

To determine the true bearing of a line from an observation on Polaris at either eastern or western elongation, first the Eastern Standard Time of elongation is computed (See Example 1). The line AB has been established (See Fig. 3). Two flashlights and a reflector are required. The reflector can be made from a piece of white paper or a piece of tin painted white (See Fig. 2). One flashlight is used to give sight at B. This is done by holding the flashlight back of a white piece of paper which is held back of the range pole or plumb bob string. The illumination of the cross-hairs is affected by using a flashlight and the reflector which is fastened to the sun shade on the telescope. To locate Polaris (See Fig. 1).

The transit is set up at A and the horizontal angle BAP is recorded at the computed Eastern Standard Time of elongation. If the transit is in perfect adjustment a single observation will suffice. To take up any error in the transit, four readings

should be taken alternating the telescope direct and reverse as shown under Observed Values in the Example. Two of these readings should be before and two after the computed E. S. T. of elongation. The east and west movement of Polaris is inappreciable as much as ten minutes immediately before and after elongation.

The Azimuth angle of Polaris, NAP can be computed from tables in the U. S. Ephemeris (See Example). The latitude and longitude of the place can be determined by scaling from an accurate map.

EXAMPLE

County: _____ Route: _____

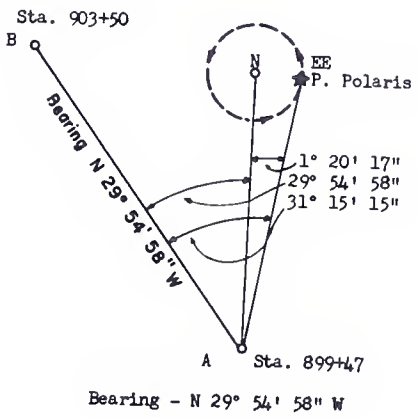
Date: August 18, 1944 E. S. T.: $10^h\ 04^m\ 13''$ P. M.

Latitude: 41° 20′ N Longitude 77° 00′ W

E. Elongation Lat. 40°	$9^h\ 56.9^m$	P. M.	(U. S. Eph. Page 1-8)
Lat. correction	$+\ 0.13^m$		(U. S. Eph. Page 9)
Long. Corr. $\left(\frac{77}{15} \times 0.16^m\right)$	$-\ 0.82^m$		
Local Mean Time	$9^h\ 56.21^m$		
Corr. from 75th to 77th Meridian	$+\ 8$		(4^m bet. each Meridian)
Eastern Standard Time	$10^h\ 04.21^m = 10^h\ 04^m\ 13''$ P. M.		

OBSERVED VALUES

Time	Hor. Angle	B.A.P.
$10^h\ 01^m$ P. M.	31° 15′ 00″	direct
$10^h\ 03^m$ P. M.	31° 15′ 30″	reverse
$10^h\ 05^m$ P. M.	31° 15′ 30″	reverse
$10^h\ 07^m$ P. M.	31° 15′ 00″	direct
Mean	31° 15′ 15″	



Bearing - N 29° 54′ 58″ W

AZIMUTH OF POLARIS

Declination 88° 59′ 43.8″ (U. S. Eph. Page 1-8)

Azimuth of Polaris at Elongation (U. S. Eph. Page 9)

Declination

88° 59′ 40″–88° 59′ 43.8″–88° 59′ 50″

Latitude		Azimuth	
40° 00′	1° 19′ 57″	1° 19′ 52″	1° 19′ 44″
41° 20′	Interpolated	1° 20′ 17″ = Azimuth	
42° 00′	1° 21′ 11″	1° 21′ 06″	1° 20′ 58″

8–15 MERIDIAN BY OBSERVATION ON POLARIS AT ANY HOUR ANGLE

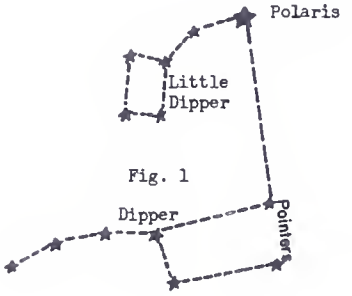


Fig. 1

Fig. 2

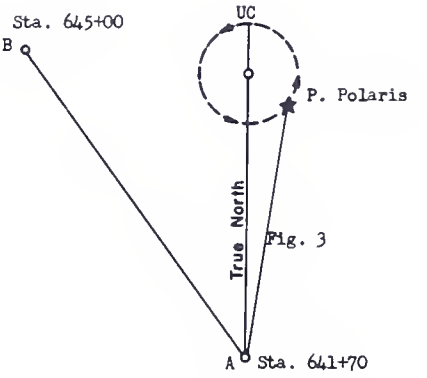


Fig. 3

Observations on Polaris or the Sun to determine true bearings of survey centerlines should be made with an engineer's transit at the beginning of short surveys and three to five miles on long surveys. If the location where an observation is desired is in the center of an existing highway where the observer would be disturbed by traffic an offset line should be established that would eliminate this condition.

To determine the true bearing of a line from an observation on Polaris at any hour angle. The line AB has been established (See Fig. 3). Two flashlights and a reflector are required. The reflector can be made from a piece of white paper or a piece of tin painted white. (See Fig. 2). One flashlight is used to give sight at B. This is done by holding the flashlight back of a white piece of paper which is held back of the range pole or plumb bob string. The illumination of the cross-hairs is affected by using a flashlight and the reflector which is fastened to the sunshade on the telescope. To locate Polaris (See Fig. 1).

The transit is set up at A and the horizontal angle B.A.P. and the correct Eastern Standard Time is recorded. If the transit is in perfect adjustment a single observation will suffice. To take any error in the transit, four readings should be taken alternating the telescope direct and reverse as shown under observed value in the example. The four readings should be at regular spaced intervals. The mean of these readings is used in your computations. The Eastern Standard Time is then changed to local time.

Upper culmination of Polaris for the meridian of Greenwich eivil date and mean time may be found for any date in the year in the U. S. Ephemeris. If the time of upper culmination on the date of observation is more than eleven hours fifty-eight minutes from the time of the observation the proceding or succeeding date and time of upper culmination, whichever it may be, will be used to compute the hour angle. Azmuth of Polaris at all hour angles eleven hours fifty-eight minutes east or west of upper culmination may be found in the U. S. Ephemeris. If time of upper culmination used is before time of observation the Azimuth Angle will be east and if time of upper culmination used is after time of observation the Azimuth Angle will be west.

The latitude and longitude of the place may be determined by scaling from an accurate map.

EXAMPLE

County:____ Route:__ Date of Observation:

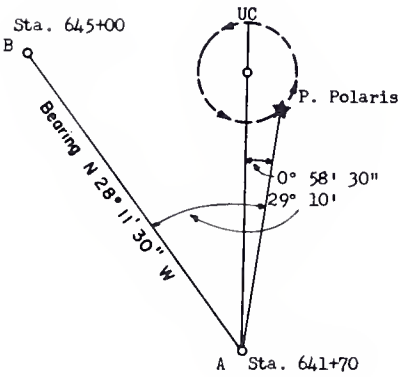
Latitude: 40° 20'____ Longitude: 78° 20'____

OBSERVED VALUES

	E.S.T.	Hor. Angle B.A.P.
Direct	$10^h\ 21^m$ P.M.	29° 07'
Reverse	$10^h\ 23^m$	29° 09'
Reverse	$10^h\ 25^m$	29° 11'
Direct	$10^h\ 27^m$	29° 13'
Mean	$10^h\ 24^m$ P.M.	29° 13'

Mean E.S.T. of Observation $10^h\ 24^m$ P.M.
(78° 20'–75") = 3° 23' = 3.333 x $4'^m$ – 13.33^m

$10^h\ 15.57^m$



UPPER CULMINATION (July 2, 1944)

Upper Culmination Cr. 7" 04.2^m A.M. (U.S. Eph. Page 1-9)
Long. Corr. – 0.84^m

7" 03.35^m A.M. July 2, 1944

Local Mean Time of Observation $10^h\ 10.67^m$ P.M. July 1, 1944
Local Mean Time of U. C. $7^h\ 03.36^m$ A.M. July 2, 1944

Hour Angle of Polaris, East $8^h\ 52.69^m$

Azimuth of Polaris at any Hour Angle (U. S. Eph. Page 10-11)

Latitude			
42° 00'	42° 20'	44° 00'	Declination 88° 59' 38.4" (U. S. Eph. Page 1-8)
Hour Angle	Azmiuth		
$8^h\ 48.6^m$	58.9'	59.2' 60.8'	Corr. for Dec. 3.3' (U. S. Eph. Page 10-11)
$8^h\ 52.69$	Interpol.	58.2	
$8^h\ 58.5^m$	56.5'	56.8' 58.2'	Corrected Azimuth $\frac{88.2'}{58.5'}$ = 0° 58' 30"

8–16 MERIDIAN BY OBSERVATION OF THE SUN

Observations on Polaris of the Sun to determine true bearings of survey centerlines should be made with an engineer's transit at the beginning of short surveys and every three to five miles on long surveys.

The bearing of any given line AB may be determined by observing the sun with an engineer's transit having a well adjusted vertical circle or half circle. The transit is set up at A on the line AB. Horizontal Angles are clockwise readings from B to sun.

Fig. 1

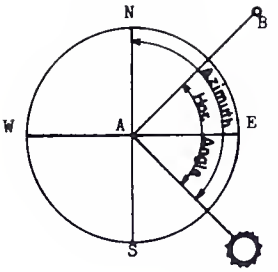


Fig. 2

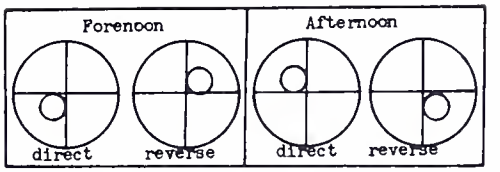
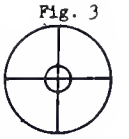


Fig. 3



An observation and readings may be made (1) either by observing the sun directly through a dark colored glass, or (2) by allowing the sun's image to fall on a white card held behind the eyepiece. If the second method is used the reflection of the cross-hairs can be darkened by adjusting the eyepiece. Do not hold the card too close as the brightness of the sun's image will obscure the cross-hairs.

If the transit has a full vertical circle one observation should be taken with the telescope direct and another with the telescope reversed as shown in Figure 2. If your transit does not have a full vertical circle both observations will be direct.

For each reading, the Horizontal Angle, Vertical Angle and Correct Eastern Standard Time should be recorded. Observations are computed for the Mean Reading.

Another practical method of observation is to center the cross-hairs in the sun (See Fig. 3.) Using this method five or six observations should be taken as fast as they can be read accurately and the computations be made from the mean of the recordings.

The latitude of the place may be determined by scaling from an accurate map.

The U. S. Ephemeris is used to obtain the Declination of the Sun.

Corrections for refraction and parallax are obtained from Page 8–14.

When it is noon at Greenwich it is 7:00 A. M. Eastern Standard Time on the 75th meridian.

Between 8:30 A. M. and 10:30 A. M. or between 2:00 P. M. and 3:30 P. M. is the best time to take an observation on the sun, since a maximum error in observation occurs when the sun is either near the meridian or less than 15° from the horizon.

EXAMPLE OF FIELD NOTES

County ..... Route .....
Transit Sta. ..... Rod. Sta. .....
Date ..... Latitude .....

Using Method Shown in Fig. #2

Tel. Sun	E.S.T.	Hor. Angle	Vert. Angle
Dir.	8:42 A.M.	65° 16′ 30″	44° 08′ 30″
Rev.	8:44 A.M.	64° 46′ 30″	43° 48′ 00″
M'n	8:43 A.M.	65° 01′ 30″	43° 58′ 15″

Using Method Shown in Fig. #3

E.S.T.	Hor. Angle	Vert. Angle
8:42 A.M.	64° 42′ 00″	43° 20′ 30″
First & Last	64° 49′ 30″	43° 36′ 00″
Observation	64° 57′ 00″	43° 51′ 00″
only need be	65° 06′ 00″	44° 06′ 30″
recorded	65° 13′ 00″	44° 20′ 30″
8:44 A.M.	65° 21′ 30″	44° 35′ 00″
8:43 A.M.	65° 01′ 30″	43° 58′ 15″
		Mean

Table 8–1

CORRECTION FOR REFRACTION

Apparent Altitude		*Refraction*		*Apparent Altitude*		*Refraction*		*Apparent Altitude*	*Refraction*	
°	′	′	″	°	′	′	″	°	′	″
7	30	6	53	12	0	4	25	25	2	3
	40		45	12	30		15	26	1	58
	50		37	13	0	4	5	27		53
8	0		30	13	30	3	56	28		48
	10		22	14	0		47	29		44
	20		15	14	30		39	30		40
	30		8	15	0		32	32		32
	40	6	02	15	30		25	34		25
	50	5	55	16	0		19	36		19
9	0		49	16	30		13	38		14
	10		43	17	0		7	40		9
	20		38	17	30	3	1	42		4
	30		32	18	0	2	56	44	1	0
	40		26	18	30		51	46	0	56
	50		21	19	0		46	48		52
10	0		16	19	30		42	50		48
	20	5	6	20	0		37	55		40
	40	4	57	21	0		29	60		33
11	0		48	22	0		22	65		27
	20		40	23	0		15	70		21
	40		32	24	0		9	80		10
12	0	4	25	25	0	2	3	90	0	0

Table 8–2

CORRECTION FOR PARALLAX IN ALTITUDE

Apparent Altitude	0°	17°	26°	38°	48°	56°	63°	70°	77°	90°
Parallax....	8.9″	8.5″	8″	7″	6″	5″	4″	3″	2″	0″

Table 8–3

MINUTES IN DECIMALS OF A DEGREE

1	.0167	11	.1833	21	.3500	31	.5167	41	.6833	51	.8500
2	.0333	12	.2000	22	.3667	32	.5333	42	.7000	52	.8667
3	.0500	13	.2167	23	.3833	33	.5500	43	.7167	53	.8833
4	.0667	14	.2333	24	.4000	34	.5667	44	.7333	54	.9000
5	.0833	15	.2500	25	.4167	35	.5833	45	.7500	55	.9167
6	.1000	16	.2667	26	.4333	36	.6000	46	.7667	56	.9333
7	.1167	17	.2833	27	.4500	37	.6167	47	.7833	57	.9500
8	.1333	18	.3000	28	.4667	38	.6333	48	.8000	58	.9667
9	.1500	19	.3167	29	.4833	39	.6500	49	.8167	59	.9833
10	.1667	20	.3333	30	.5000	40	.6667	50	.8333	60	1.0000

Figure 8–1

Form 473-F(6-60) COMMONWEALTH OF PENNSYLVANIA
Department of Highways
AZIMUTH BY ALTITUDES OF THE SUN

Route No._____ Book No._____ Page No._____ Township _____
Borough _____
Sta._____ To Sta._____ _____sight County _____

Date June 4, 1964 Mean Time 2:15 pm EST

Mean Vertical Angle 34°16.7' Mean Horizontal Angle 121°39.4'

Latitude N 41°28.1' Longitude W 76°51.9'

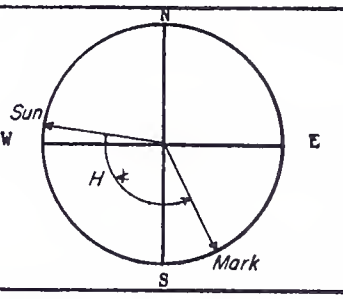
Temp. 82° F Elev. (H.I.) 1040 FT ASL

Stand. time 75 th. meridian 2:15 pm
Corr. for 24 hr. basis +12h
75 th. meridian time 14:15
Corr.-time zone at obs. + 5h
G.C.T. (Greenwich Civil T.) 19:15

*Sun's d^{0h} (Table I) K & E(±) -22°24.7'
Sun's change since 0^h(x) 5.6'
Sun's d = (±) -22°30.3'

Note:
*d=Sun's declin. (+) Mar. 22 to Sept. 22
(-) Sept. 22 to Mar. 22
h=Sun's true altitude
l=Latitude measured from map

Measured altitude (Field Vert.) 34°16.7'
-(1.4' x 0.94 x 0.98)+0.12' =(-) 1.2'
Refr. Temp. Bar. Par.
True altitude h = 34°15.5'



MACHINE COMPUTATION

$$\text{Cos } Z = \frac{(\pm)\text{Sin d} - \text{Sin h Sin l}}{\text{Cos h Cos l}}$$

$$= \frac{(\pm)\text{Sin } -22°30.3' - (\text{Sin } 34°15.5' \times \text{Sin } 41°28.1')}{\text{Cos } 34°15.5' \times \text{Cos } 41°28.1'}$$

$$\text{Cos } Z = \frac{(\pm)0.38276 - (0.56292 \times 0.66221)}{0.82651 \times 0.74932}$$

$$\text{Cos } Z = \frac{(\pm)0.38276 - 0.37277}{0.61932}$$

$$\text{Cos } Z = \frac{(\pm)+0.00999}{0.61932} = +0.01613$$

Z = N 89° 04.6' W

LOGARITHMIC COMPUTATION

$$\text{Cos } Z = \frac{(\pm)\text{Sin d}}{\text{Cos h Cos l}} - \text{Tan h Tan l}$$

Add:
d=-22°30.3' --- Log Sin = 9.58293-10
h=34°15.5' --- CoLog Cos = 0.08275
l=41°28.1' --- CoLog Cos = 0.12533
Antilog$_1$ = 0.61803 Log 9.79101-10
or 1.79101

Add:
h=34°15.5' --- Log Tan = 9.83321-10
l=41°28.1' --- Log Tan = 9.94632-10
Antilog$_2$ = 0.60191 Log 19.77953-20
or 1.77953

Subtract:
Antilog 1 = 0.61803
Antilog 2 = 0.60191
Cos Z (±) 0.01612
Z = N 89° 04.6' W

REMARKS:

Z is the horizontal angle the sun makes with the meridian of observation.
Minus value of Cos Z is an angle greater than 90°.
Observation in morning = bearing east of north and vice versa.

Sun's Bearing (Z) N 89°04.6' W
Horizontal Angle 121° 39.4' (Mark to sun)
Bearing of Line S 30°44.0' E

CHAPTER NINE

AERIAL SURVEYS

9–1 Aerial surveying is the production of map data by photogrammetric methods. A principal advantage of aerial surveys for highways is the ability to obtain two to nine times the coverage normally surveyed by ground methods. Moreover, aerial surveys properly employed add the benefits of improved locations and design which decrease construction costs and improve highway services.

9–2 Specifications controlling photogrammetric mapping and aerial surveys for the Department of Highways are:

A. Division One—Specifications for Aerial Photography and Topographic Mapping When Used For (1) Highway Location Studies, (2) Preliminary Highway Design.

B. Division Five—Specifications for Aerial Photography and Topographic Mapping When Used For Final Highway Design.

9–3 All consulting engineers and commercial mapping firms are required to produce map data which will conform to the provisions of the above specifications. Map data by the Department's Photogrammetric Section is also prepared in accordance with these specifications.

A. AERIAL PHOTOGRAPHY

(1) Aerial photography may be obtained at almost any scale desired by the highway engineer. Photography at a scale of one (1) inch to 400 feet will cover a width of 3600 feet of ground area. Photography at a scale of one (1) inch to 200 feet will cover a width of 1800 feet. Table 9-1 on photogrammetric data will describe relationship between scales, flight height, and area coverage.

(2) Aerial photography could be used by the location engineer to locate a line or lines to be run in the field by conventional methods. A survey corps, using the photographs, could establish the line or lines as selected by the location engineer. This procedure would seem feasible on five-digit roads where mapping by photogrammetric methods is not required.

(3) Aerial photography of this type can also be used to an advantage on drainage problems, soils investigation, traffic studies and maintenance problems.

B. PHOTOGRAPHIC ENLARGEMENTS

(1) Photographic enlargements may be obtained with a 2 to 5 time enlargement ratio from any existing aerial photography.

C. GEODETIC SURVEYS

(1) Positions of horizontal control points must be paneled with white muslin cloth, or other approved material, in the field prior to aerial flights. Paneling need be accomplished only on projects for mapping purposes. Panels shall be of the size indicated in Table 9–1 based on map scale and flight altitude.

(2) Distance for horizontal control shall be obtained by use of electronic distance measuring systems (Tellurometer or Geodimeter) or by the use of precise taping methods utilizing a standardized tape. Horizontal angles shall be turned utilizing precision theodolites of the Wild T-2 type.

(3) Vertical mapping control shall be established by differential leveling utilizing self-leveling levels or a standard wye level. Vertical control points must be selected so they can be positively identified in the aerial photography by photo-interpretation.

(4) Accuracy of geodetic control surveys shall be in accordance with Tables 9-2, 9-3, and 9-4 of this chapter and the applicable division of Department Mapping Specifications.

D. PHOTOGRAMMETRIC MAPPING

(1) **Area Studies**

Topographic mapping prepared by photogrammetric methods can be obtained for area studies at map scales of one (1) inch to 400 feet, 600 feet, 800 feet or 1000 feet. Contour intervals will vary from 10 to 20 feet depending on map scale.

(2) **Location and Preliminary Design**

Topographic mapping prepared by photogrammetric methods is usually obtained at a scale of one (1) inch to 200 feet, with a five-foot contour interval, for location and preliminary design.

However, in urban areas, it may be desirable to obtain mapping at a scale of one (1) inch to 100 feet with a two-foot contour interval.

(3) **Final Design**

The map scale normally produced for this phase of highway engineering is one (1) inch to 50 feet with a 1 or 2 foot contour interval.

However, photogrammetric cross-sections can be delivered in lieu of contours, if desired. Maps would show, in this case, only planimetric features.

(4) **Bridge Sites**

Mapping for the study of bridge relocation sites can be produced at scales of one (1) inch to 20, 50, 80 or 100 feet. The mapping will have a 1 or 2 foot contour interval. Mapping at these scales will, undoubtedly, cover all possible relocation sites for the bridge with sufficient mapping information to analyze roadway approach alignments. Also, overlays for engineering soils classification and drainage areas can be produced to give the bridge engineer detailed information within the project area.

Table 9–1

PHOTOGRAMMETRIC MAPPING DATA

RATIO OF MAP SCALE TO PHOTOGRAPHY SCALE = 5:1

Map Scale (Ft. to 1")	Photo Scale (Ft. to 1")	Flight Height (Feet)	Maximum Relief (Feet)	Feasible Contour Interval (Feet)	Possible Accuracy Of 90% of Spot Elevations	One Flight Line		Each Additional Flight Line		
						Width Of Photo Coverage (Feet)	Width Of Map Coverage (Feet)	Width Of Photo Coverage (Feet)	Width Of Map Coverage (Feet)	Desirable Spacing Of Panel Points
20	100	600	147	0.5	0.13	900	700	630	630	150
40	200	1200	294	1.0	0.25	1800	1400	1260	1260	300
50	250	1500	367	2.0	0.31	2250	1750	1575	1575	300
80	400	2400	588	2.0	0.50	3600	2800	2520	2520	500
100	500	3000	735	2.5	0.63	4500	3500	3150	3150	600
200	1000	6000	1470	5.0	1.25	9000	7000	6300	6300	1200

Map Scale (Ft. to 1")	Photo Scale (Ft. to 1")	5' Manuscripts Per Mile	Models Per Mile	Linear Coverage Per Model (Feet)	Models Per 5' Sheet	Non Stereo Photos Per Mile	Panel Size
20	100	4.40	15.09	350	3.43	7.54	0.5' x 5'
40	200	2.20	7.54	700	3.43	3.77	1' x 5'
50	250	1.76	6.03	875	3.43	3.02	1' x 5'
80	400	1.10	3.77	1400	3.43	1.88	1' x 5'
100	500	0.88	3.02	1750	3.43	1.51	1' x 5'
200	1000	0.44	1.51	3500	3.43	0.75	1' x 10'

Table 9–2

CLASSIFICATION AND STANDARDS OF ACCURACY TRIANGULATION

	First-order			Second-order		Third-order
	Class I (Special)	*Class II* (Optimum)	*Class III* (Standard)	*Class I* Class	*Class II*	
Principal uses	Urban surveys, scientific studies	Basic network	All other.	Area networks and supplemental cross arcs in national net	Coastal areas, inland waterways and engineering surveys	Topographic mapping
*Spacing of arcs or principal stations**	Stations: 1-5 miles or greater as required	Arcs: 60 miles. Stations: 10-15 miles	Stations: 10-15 miles	Stations: 4-10 miles	As required	As required
Strength of figure						
Sum R_1 between bases						
Desirable limit	25	60	80	80	100	125
Maximum limit	30	80	110	120	130	175
Single figure						
Desirable limit						
R_1	5	10	15	15	25	25
R_2	10	30	50	70	80	120
Maximum limit						
R_1	10	25	25	25	40	50
R_2	15	60	80	100	120	170
Base measurement						
Actual error not to exceed	1 part in 300,000	1 part in 300,000	1 part in 300,000	1 part in 300,000	1 part in 150,000	1 part in 75,000
Probable error not to exceed	1 part in 1,000,000	1 part in 1,000,000	1 part in 1,000,000	1 part in 1,000,000	1 part in 500,000	1 part in 250,000

Table 9–2 (Cont'd.)

	First-order			*Second-order*		*Third-order*
	Class I	*Class II*	*Class III*	*Class I*	*Class II*	
Triangle closure						
Average not to exceed	1″	1″	1″	1″.5	3″	5″
Maximum seldom to exceed	3″	3″	3″	5″	5″	10″
Side checks						
Ratio of maximum difference of logs of sides to tab. diff. for 1″ of log sine of smallest angle	1.5	1.5–2	2	2–4	4	10–12
OR in side equation test, average corr. to direction not to exceed	0″.3	0″.4	0″.4	0″.6	0″.8	2″
Astro. Azimuths						
Spacing-figures	6–8	6–10	8–10	8–10	10–12	12–15
Probable error	0″.3	0″.3	0″.3	0″.3	0″.5	2″.0
Closure in length						
(also position when applicable) after side and angle conditions have been satisfied, should not exceed	1 part in 100,000	1 part in 50,000	1 part in 25,000	1 part in 20,000	1 part in 10,000	1 part in 7,500

* Additional stations of same accuracy may be interspersed among principal stations

Table 9–3

TRAVERSE

	First-order	*Second-order*	*Third-order*
Number of azimuth courses between azimuth checks not to exceed	15	25	50
Astronomical azimuth: Probable error of result	0″.5	2″.0	5″.0
Azimuth closure at azimuth check points not to exceed*	2 sec. $\sqrt{N}$ or 1.0 sec. per station	10 sec. $\sqrt{N}$ or 3.0 sec. per station	30 sec. $\sqrt{N}$ or 8.0 sec. per station
Distance measurements accurate within	1 in 35,000	1 in 15,000	1 in 7,500
After azimuth adjustment, closing error in position not to exceed*	0.66 ft. $\sqrt{M}$ or 1 in 25,000	1.67 ft. $\sqrt{M}$ or 1 in 10,000	3.34 ft. $\sqrt{M}$ or 1 in 7,500

N is the number of stations for carrying azimuth

M is the distance in miles

* The expressions for closing errors in traverse surveys are given in two forms. The expression containing the square root is designed for longer lines where higher proportional accuracy is required. The formula which gives the smaller permissible closure should be used.

Table 9–4

LEVELING

	First-order	*Second-order*		*Third-order*
		Class I	*Class II*	
Spacing of lines and cross-lines	60 miles	25-35 miles	6 miles	Not specified
Average spacing of permanently marked bench marks along lines, not to exceed	1 mile	1 mile	1 mile	3 miles
Length of sections	½–1 mile	½–1 mile	½–1 mile	Not specified
Check between forward and backward running between fixed elevations or loop closures, not to exceed	4mm $\sqrt{K}$ or 0.017 ft. $\sqrt{M}$	8.4mm $\sqrt{K}$ or 0.035 ft. $\sqrt{M}$	8.4mm $\sqrt{K}$ or 0.035 ft. $\sqrt{M}$	12mm $\sqrt{K}$ or 0.05 ft. $\sqrt{M}$

K is the distance in kilometers

M is the distance in miles

CHAPTER TEN

BRIDGE AND CULVERT SITE SURVEYS

10–1 The purpose of a bridge is to carry traffic over a water course, ravine, highway, railroad or other obstruction or hazard, and also under a highway, railroad or other construction with the minimum amount of cost involved but with the maximum amount of serviceability providing for present and future requirements. Culverts serve a similar purpose.

10–2 Bridge and culvert site surveys are made to properly locate such a structure so that all necessary and accurate data will be obtained for the location and design of a new structure or to incorporate an existing structure into the new construction.

10–3 The data must necessarily be complete, as well as accurate, taking into consideration traffic requirements, alignment, sight distances, waterway requirements and also channel corrections and improvements to safeguard the proposed highway, but yet provide for economical construction.

10–4 When making studies for bridge and culvert locations involving water courses, consideration must be given to:

1. Width of channel.
2. Permanency of channel.
3. Straightness of channel on each side of the proposed bridge or culvert.
4. Islands, tributary streams, obstructions or other conditions which may deflect or alter the stream current.
5. Relation of proposed crossing to sharp bends in the stream channel.
6. Presence of high channel banks.
7. Possibility of crossing the stream as nearly at right angles as possible.
8. Possibility of eliminating horizontal curves in both approaches to bridge or culvert and on the bridge or culvert.
9. The grade of highway over the bridge or culvert.
10. Economics, which involve:
    a. Depth to good bearing foundation.
    b. Materials required to be excavated.
    c. Quality of bearing material.
    d. Height of substructure.

10–5 When making studies for bridge and culvert locations over a ravine, highway, railroad or other obstruction or hazard, and also under a highway, railroad or other obstruction, consideration must be given to:

1. Width of ravine, highway, railroad or other obstruction, construction or hazard.
2. Permanency of the highway, railroad or other obstruction, construction or hazard to be crossed.

3. Alignment of such highway, railroad or ravine.
4. Future widening of such highway or additional trackage required which would affect the location of the crossing.
5. Relation of proposed crossing to curvature of existing highway or railroad, which would warrant a new location for the crossing but not materially affecting the general alignment of the new highway.
6. Presence of high ground or banks on either side of the area to be crossed, which might eliminate expensive foundations.
7. Possibility of crossing the area as nearly at right angles as possible.
8. Possibility of eliminating horizontal curves in both approaches to the structure or over the structure.
9. The grade of highway.
10. Economics, which involve:
    a. Depth to good bearing foundation.
    b. Materials required to be excavated.
    c. Quality of bearing material.
    d. Height of substructure.

10–6 When locating the highway, some sacrifice is frequently necessary for the bridge site, as well as for the highway approaches and no short-sighted attitude should be assumed towards either part of the problem.

10–7 A highway alignment which is on a tangent has much in its favor, although it may be necessary to locate structures on a skew. The cost of the foundation work increases rapidly as the angle of skew increases.

10–8 To avoid the angle of skew altogether, or to lessen it, may require horizontal curves in the highway alignment and these in themselves are not objectionable if used with moderation, but in this day of high speeds, sharp curves are not permitted. Such curves, when they are immediately adjacent to, or when they extend onto the bridge floor, are undesirable and dangerous.

10–9 Vertical curves extending onto a bridge floor seriously complicate the construction and this is especialy true when the bridge is on a skew. A concave grade line presents an appearance of sag and weakness, and makes floor drainage difficult. Properly, the grade line from each end of the structure should be downward in order to harmonize with the camber provided on the floor and pleasing results will be secured. The alignment of a highway is a part of the construction which may be considered permanent; therefore this alignment must be given the most careful consideration.

10–10 A narrow and deep gorge or ravine with rock on sides and bottom is an ideal location for a bridge or culvert but is generally not available.

10–11 Where a stream channel broadens out and the water then floods large areas, the velocity of the stream is greatly reduced, silt is deposited, resulting in probable poor foundation material and here the stream, in times of flood, is difficult to control due to the many causes which may easily change the location or the main channel. Frequently such a location for a bridge would be ideal for the alignment and grade of the highway, but the resulting cost for the bridge would not compare favorably with another structure in a proper location which would provide for the same flood conditions.

10–12 In a similar manner the location of a bridge and culvert may be ideal for the alignment and grade of the highway, but excessive costs of track work, maintaining railroad or highway traffic, removal of buildings, utility structures or other obstructions, may be greatly decreased by slightly modifying the alignment to provide a location for the bridge or culvert at a nominal cost.

10–13 In making these surveys, the highway center line should be started at least one thousand (1000) feet back of the crossing and should be carried the same distance beyond, excepting in cases where relocations are necessary and here the length of the bridge and culvert survey will be determined by the actual requirements in the field.

10–14 At a stream crossing, a point or hub should be set on the center line of the highway conveniently near the stream edge and from this point a random line should be run up and down the stream for at least five hundred (500) feet each way. The plus at the point of intersection on the center line, as well as any angle turned in running the random line, must be recorded. From this random line, offsets to the stream edges should be taken at one hundred (100) foot intervals or less, along the full length of the line so that both shore lines can be located and recorded. The results of these notes, when worked up, should give an accurate plot of the stream for at least five hundred (500) feet each side of the survey center line. Offsets from the random line may be taken when taking cross-sections in order to save time when running center line. Grade separations shall be handled in the same manner, but the random line should be run at least one hundred (100) feet each side of the center line and offsets taken to the tracks at not over twenty-five (25) foot intervals.

10–15 All measurements and angles shall be tied into the highway survey center line.

10–16 At least one bench mark shall be established on each side of an approved structure site and at such distance therefrom that each will be easily accessible for preliminary surveys and construction work. These bench marks shall be used for all cross-sections and elevations for the structure or highway.

10–17 Topography shall be taken in detail within a reasonable area of each site so that all existing conditions that may effect the structure layout or design are noted.

10–18 Sufficient data must be obtained in order that the adequacy or inadequacy of an existing structure can be determined for railroad traffic, highway traffic, or flood discharge. The waterway opening may be sufficient and the alignment for highway traffic satisfactory, but the roadway width may be too narrow. Certain types of bridges can economically be widened, and this should be given consideration.

10–19 If a new structure is required, it should be determined if it will be economical to use any part of the old structure. The construction, design, location and condition of the structure will be the determining factors.

10–20 Where a new structure over a stream is required, obtain complete data so that a proper waterway opening can be designed. Also obtain all field data required in connection with the design of the structure itself. Follow the requirements of Form 444 for the required data.

10–21 For the waterway design, obtain the stream bed slope and the water surface slope for a minimum distance of five hundred (500) feet on each side of the bridge. If within this one-thousand (1000) foot range there is a dam or other similar obstruction, record its height, type, and other physical details. Maximum flood elevations should be recorded with dates of occurrence. For a bridge span of one hundred (100) feet or over, obtain if possible, the elevation of the two highest known floods. The proper angle between the stream and the highway center line should be determined, and this may at times, make necessary either wholly or partially, the relocation of the stream channel. Such channel changes shall be kept to an economical minimum and still furnish adequate protection to the highway.

10–22 For a proposed structure over or under a highway or railroad, cross-sections should be taken at ten (10) foot intervals, and all breaks, on both the highway or railroad center line, on each side of the center line of the proposed structure, and for a sufficient distance to cover the proposed improvement. For a proposed structure over a stream, cross-sections should be taken at twenty-five (25) foot intervals and all breaks of the stream and adjacent banks, starting at the limits of the proposed structure, and for a sufficient distance both up and down stream. Within the limits of the proposed structure, cross-sections should be taken parallel with the highway center line as considered necessary by the district engineer, but at not over ten (10) foot intervals and all breaks. All sections should be carried across and at least up to the flood plane, and evidences of erosion should be recorded.

10–23 If extensive channel relocations are to be made other than at bridge sites, procure sufficient data so that the proposed channel section can be computed as to its sufficiency. Likewise, where a retaining wall is to be constructed or a fill made within the lines of the existing stream banks, data must be submitted so that the effect of such obstructions to flood flow can be determined. For proposed channel relocations, as well as for fill or wall obstructions, show present as well as proposed conditions, both in plan and cross-sections. Cross-sections must be carried for full width of present channel, including overflow channel, and at least up to flood elevation. Stream bed and water surface slopes must be shown, as well as the drainage area which the channel will accommodate. Follow the requirements of Form 444 as for a new structure.

10–24 After the location of a bridge over a stream has been chosen, it becomes necessary to determine how much waterway should be provided before further progress can be made in deciding upon an economical and proper structure. The importance of this question varies with the size, type, and cost of the bridge.

10–25 The size of such a bridge opening is dependent upon a number of considerations; some of which are theoretical and some practical. In a built-up community, where insufficient capacity may result in danger to the bridge, erosion of the channel and destruction of property, it is usually advisable to provide for extraordinary flood flow. Conversely, in regions where no damages will result from too small an opening, an opening large enough to pass the frequent flood is all that is necessary. The question is largely one of judgment and experience based upon local conditions, knowledge of past floods, and an understanding of the principles upon which an estimate can be made of the maximum flood which may reasonably be expected to occur. It is first necessary, therefore,

to consider the site at which the bridge will be built, and then determine what run-off to provide for. After this is determined, the size of opening required to discharge the run-off is easily calculated, having been given the proper data with which to work, obtained by a survey of the site.

10–26 The use of empirical formulae for determining the size of waterway openings usually leads to inaccuracies, as they fail to take into account the conditions at the bridge site, namely, the slope of the channel immediately above and below the bridge, and the dimensions and shape of the opening upon which depend the discharge capacity of the bridge.

10–27 The various empirical formulae may be used as a guide in estimating the necessary size of opening, in a preliminary way, where only general information is at hand and the value of the terms substituted therein are known to fit local conditions. The use of such formulae should not displace careful observations and the exercise of intelligent judgment in the application of proper data and formulae for fixing the final area and shape of opening.

10–28 An efficiency of one hundred and twenty-five (125) per cent shall be provided for arches or structures under fills greater than five (5) feet.

10–29 The best estimate of the amount of run-off may be secured from careful measurement of all stages of the stream up to extreme flood height and extending over a long period of years, but even such records may be exceeded. However, not having such data, another method of estimating maximum discharge is to compare the watershed under consideration with others of similar size, physical character, and rainfall on which the run-off has been accurately measured over a period of years.

10–30 The area of the watershed can be quickly and accurately determined by the combined use of of aerial photographs and accurate photogrammetric contour maps. Drainage watersheds can be plotted for culvert and bridge design calculations, and bridge sites and aproaches may be selected, preliminary grading studies made, and other pertinent information obtained, supplemented by such other additional information from the field as is needed to choose the size and design.

10–31 The following table shows maximum flood run-offs for Pennsylvania streams, in cubic feet per second, for drainage areas. This table, based on data collected by the Water and Power Resources Board of Pennsylvania, shows the maximum discharge which may be expected to occur from drainage areas of the sizes given. These discharge values may be modified somewhat when there are conditions existing on the particular drainage area under consideration, such as its shape, topography, or geology, which indicate that the maximum expected flood discharge for drainage areas of that size will not be reached, or in accordance with the discussion herein set forth.

(A) Determination of the maximum expected run-off can be secured from one of the following methods given in order of their reliability:

1. From actual measurement of flood flow and flood heights.
2. From records of flood flow in similar streams.
3. From empirical formulae.

(B) Having determined the maximum flow to be provided for, it will be necessary to have the following data available which have been obtained by accurate field survey:

1. Slope of stream throughout a distance of at least five hundred (500) feet above and five hundred (500) feet below the bridge site. (Slope of bed, low water surface and flood surface should be secured, if possible.)
2. Cross-section of channel showing width between defined banks and of flood water channel.
3. Character of channel in order to determine the co-efficient of roughness.
4. Profile of road and elevation of maximum flood.

(C) Since it is generally important that there be no contraction of the channel at the bridge site, with a consequent raising of flood elevation, the abutment should be set into the banks and be aligned with the thread of the current.

Table 10–1

1959

MAXIMUM EXPECTED RUN-OFF FOR BRIDGE OPENING DESIGNS FROM VARIOUS DRAINAGE AREAS

Area Sq. Mi.	*Discharge c. f. s.*	*Area Sq. Mi.*	*Discharge c. f. s.*
1	655	100	17,500
2	1,144	110	18,680
3	1,545	120	19,830
4	1,902	130	20,950
5	2,255	140	22,030
6	2,555	150	23,090
7	2,839	175	25,660
8	3,110	200	28,120
9	3,371	225	30,475
10	3,620	250	32,750
15	4,780	275	34,955
20	5,820	300	37,100
25	6,780	350	41,230
30	7,680	400	45,170
35	8,530	450	48,960
40	9,350	500	52,620
45	10,140	600	59,610
50	10,890	700	66,240
55	11,630	800	72,570
60	12,340	900	78,660
65	13,040	1,000	84,500
70	13,710	1,500	111,600
75	14,380	2,000	135,800
80	15,020	2,500	158,200
85	15,660	5,000	254,200
90	16,280	10,000	408,400
95	16,900	25,000	764,300

(D) The dimensions of a trial opening are then assumed in order to determine the discharge which such opening may accommodate.

(E) The following diagrams will be found helpful, if used in connection with the explanation given under "Maximum Flood Discharge."

10–32 MAXIMUM FLOOD DISCHARGE.

Bridge opening divided by wetted perimeter = Hydraulic Radius (R). Using N = .03, and slope per thousand find V at right of chart. V times opening = discharge in Sec. Ft. of bridge opening. A velocity, "V," greater than 15 shall not be used in computing the required waterway openings.

The diagram N = .03 shall be used for slopes up to and including 1% and the diagram N = .035 for slopes exceeding 1%.

Check result against table of maximum run-offs expected.

Where piers are used for wetted perimeter, add two abutment clears and one clear for each pier instead of two.

Where arch is used, use area and wetted perimeter up to height equal to 0.9 of clear.

When R. C. Boxes are used, use full area.

In general, channel openings provided shall be equal to, or greater, than that required to safely discharge floods without damage to the structure. Ample provision shall be made for underclearances, in order to permit the free passage of drift, debris, and ice in times of high water.

Attention is called to the fact that velocities exceeding the following are apt to scour the stream bottoms and some form of stream bed protection or a special design should be provided, if, such conditions exist.

1. Sand, alluvial soil and soft clay—five (5) feet per second.
2. Fine clay, loose stones or boulders—eight (8) feet per second.
3. Shale or cemented clays—twelve (12) feet per second.

Table 10–2

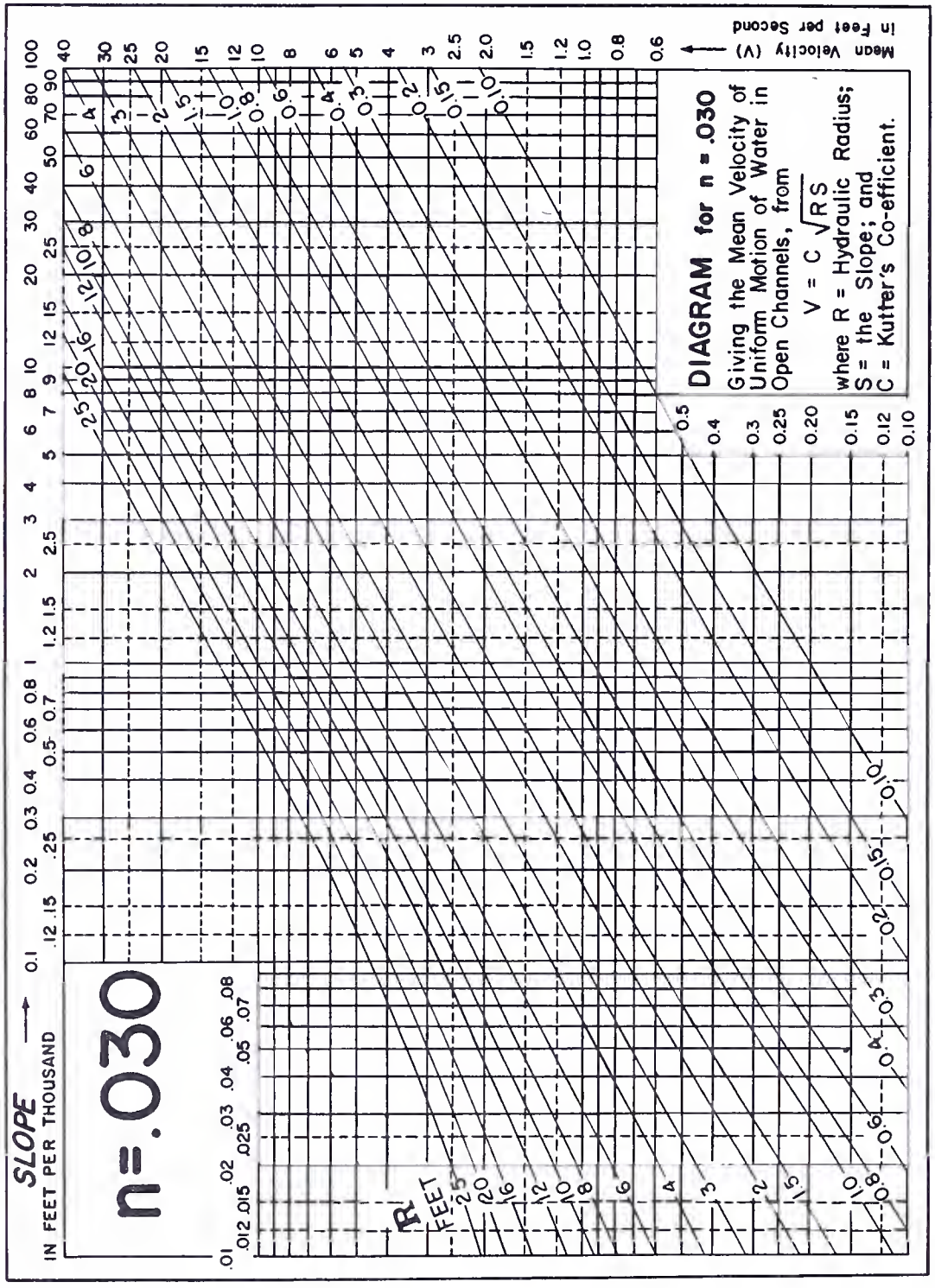

n=.030
SLOPE
IN FEET PER THOUSAND
R
FEET
DIAGRAM for n = .030
Giving the Mean Velocity of Uniform Motion of Water in Open Channels, from
V = C √RS
where R = Hydraulic Radius; S = the Slope; and C = Kutter's Co-efficient.
Mean Velocity (V)
in Feet per Second

Table 10–3

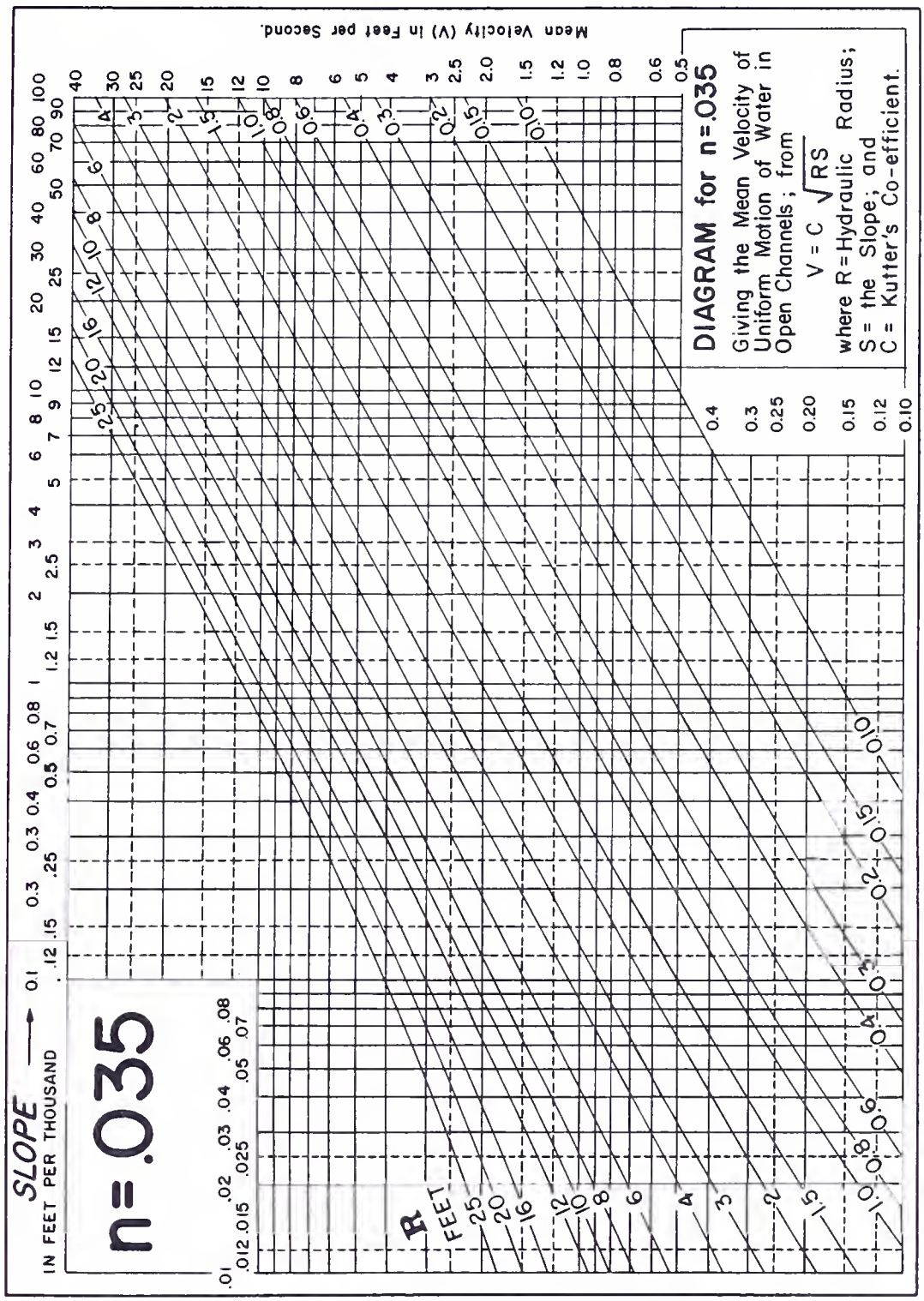

n=.035
SLOPE
IN FEET PER THOUSAND
R
FEET
Mean Velocity (V) in Feet per Second.
DIAGRAM for n=.035
Giving the Mean Velocity of Uniform Motion of Water in Open Channels; from
V = C √RS
where R=Hydraulic Radius;
S= the Slope; and
C = Kutter's Co-efficient.

Table 10–4

VALUES OF "C" IN KUTTERS FORMULA

Hydraulic Radius	*To 1% N = .030*	*1%+ N = .035*	*Hydraulic Radius*	*N = .030*	*N = .035*
.1	21.0	17.0	5.1	65.8	57.2
.2	27.0	22.0	5.2	66.0	57.4
.3	31.0	25.0	5.3	66.3	57.6
.4	35.0	29.0	5.4	66.5	57.8
.5	37.0	31.0	5.5	66.8	58.0
.6	39.0	33.0	5.6	67.0	58.2
.7	41.0	34.0	5.7	67.3	58.4
.8	43.0	35.0	5.8	67.5	58.6
.9	44.0	36.5	5.9	67.8	58.8
1.0	45.0	38.0	6.0	68.0	59.0
1.1	46.2	39.0	6.1	68.2	59.2
1.2	47.4	40.0	6.2	68.3	59.3
1.3	48.6	41.0	6.3	68.5	59.5
1.4	49.8	42.0	6.4	68.6	59.6
1.5	51.0	43.0	6.5	68.8	59.8
1.6	51.8	43.6	6.6	68.9	59.9
1.7	52.6	44.2	6.7	69.1	60.1
1.8	53.4	44.8	6.8	69.2	60.2
1.9	54.2	45.4	6.9	69.4	60.4
2.0	55.0	46.0	7.0	69.5	60.5
2.1	55.4	46.5	7.1	69.7	60.7
2.2	55.8	47.0	7.2	69.8	60.8
2.3	56.2	47.5	7.3	70.0	61.0
2.4	56.6	48.0	7.4	70.1	61.1
2.5	57.0	48.5	7.5	70.3	61.3
2.6	57.4	49.0	7.6	70.4	61.4
2.7	57.8	49.5	7.7	70.6	61.6
2.8	58.2	50.0	7.8	70.7	61.7
2.9	58.6	50.5	7.9	70.9	61.9
3.0	59.0	51.0	8.0	71.0	62.0
3.1	59.4	51.4	8.1	71.2	62.2
3.2	59.8	51.8	8.2	71.3	62.3
3.3	60.2	52.2	8.3	71.5	62.5
3.4	60.6	52.6	8.4	71.6	62.6
3.5	61.0	53.0	8.5	71.8	62.8
3.6	61.4	53.4	8.6	71.9	62.9
3.7	61.8	53.8	8.7	72.1	63.1
3.8	62.2	54.2	8.8	72.2	63.2
3.9	62.6	54.6	8.9	72.4	63.4
4.0	63.0	55.0	9.0	72.5	63.5
4.1	63.3	55.2	9.1	72.7	63.7
4.2	63.5	55.4	9.2	72.8	63.8
4.3	63.8	55.6	9.3	73.0	64.0
4.4	64.0	55.8	9.4	73.1	64.1
4.5	64.3	56.0	9.5	73.3	64.3
4.6	64.5	56.2	9.6	73.4	64.4
4.7	64.8	56.4	9.7	73.6	64.6
4.8	65.0	56.6	9.8	73.7	64.7
4.9	65.3	56.8	9.9	73.9	64.9
5.0	65.5	57.0	10.0	74.0	65.0

Table 10–5

VELOCITY OF WATER IN FEET PER SECOND, BASED ON KUTTER'S FORMULA, COEFFICIENT OF ROUGHNESS N = .030

$r = \frac{Area}{Wet\ Per.}$	$F = .264$ $S = .00005$	$F = .528$ $S = .00010$	$F = .792$ $S = .00015$	$F = 1.056$ $S = .00020$	$F = 1.320$ $S = .00025$	$F = 1.584$ $S = .00030$	$F = 1.848$ $S = .00035$	$F = 2.112$ $S = .00040$	$F = 2.376$ $S = .00045$	$F = 2.640$ $S = .00050$	$F = 2.904$ $S = .00055$
0.2	.07	.10	.13	.16	.18	.20	.21	.23	.24	.26	.27
0.4	.13	.19	.24	.29	.32	.36	.39	.42	.44	.47	.49
0.6	.18	.27	.34	.40	.45	.50	.55	.59	.62	.66	.69
0.8	.23	.35	.44	.51	.57	.63	.69	.74	.79	.83	.88
1.0	.28	.42	.53	.61	.69	.76	.83	.89	.94	1.00	1.05
1.2	.33	.49	.61	.71	.80	.88	.96	1.02	1.09	1.15	1.21
1.4	.38	.56	.69	.80	.91	.99	1.08	1.15	1.23	1.30	1.36
1.6	.43	.62	.77	.89	1.01	1.10	1.20	1.28	1.36	1.44	1.51
1.8	.47	.68	.84	.98	1.10	1.21	1.31	1.40	1.49	1.57	1.65
2.0	.51	.74	.92	1.07	1.19	1.31	1.42	1.52	1.61	1.70	1.78
2.2	.56	.80	.99	1.15	1.28	1.41	1.53	1.63	1.73	1.83	1.92
2.4	.60	.86	1.06	1.22	1.37	1.51	1.63	1.74	1.85	1.95	2.04
2.6	.64	.91	1.12	1.30	1.46	1.60	1.73	1.85	1.96	2.07	2.17
2.8	.68	.97	1.19	1.37	1.54	1.69	1.82	1.95	2.07	2.18	2.29
3.0	.72	1.02	1.25	1.45	1.62	1.77	1.92	2.05	2.17	2.29	2.40
3.2	.76	1.07	1.32	1.52	1.70	1.86	2.01	2.15	2.28	2.40	2.52
3.4	.80	1.12	1.38	1.59	1.78	1.95	2.10	2.25	2.38	2.51	2.63
3.6	.83	1.17	1.44	1 66	1.85	2.03	2.19	2.34	2.48	2.61	2.74
3.8	.87	1.22	1 50	1.72	1.93	2.11	2.28	2.43	2.58	2.72	2.85
4.0	.91	1.27	1.55	1.78	2.00	2.18	2.36	2.52	2.67	2.83	2.95
4 2	.94	1.32	1.61	1.85	2.07	2.26	2.44	2.61	2.77	2.92	3.06
4.4	.98	1.37	1.67	1.92	2.14	2.34	2.53	2.70	2.86	3.01	3.16
4.6	1.01	1.41	1.72	1.98	2.21	2.42	2.61	2.78	2.95	3.11	3.26
4.8	1.05	1.46	1.78	2.04	2.28	2.49	2.69	2.87	3.04	3.20	3.36
5.0	1.08	1.50	1.83	2.10	2.34	2.56	2.76	2.95	3.13	3.29	3.45
5.2	1.12	1.55	1.88	2.16	2.41	2.63	2.84	3.03	3.21	3.38	3.55
5.4	1.15	1.59	1.93	2.22	2.47	2.70	2.92	3.11	3.30	3.47	3.64
5.6	1.18	1.63	1.98	2.28	2.54	2.77	2.99	3.19	3.38	3.56	3.73
5.8	1.22	1.68	2.03	2.34	2.60	2.84	3.06	3.27	3.46	3.65	3.82
6.0	1.25	1.72	2.08	2.40	2.66	2.91	3.14	3.35	3.55	3.73	3.91
6.2	1.28	1.76	2.13	2.45	2.72	2.98	3.21	3.42	3.63	3.82	4.00
6.4	1.31	1.80	2.18	2.51	2.78	3.04	3.28	3.50	3.71	3.90	4.09
6.6	1.34	1.84	2.23	2.56	2.84	3.11	3.35	3.57	3.78	3.98	4.17
6.8	1.37	1.88	2.28	2.61	2.90	3.17	3.42	3.65	3.86	4.06	4.26
7.0	1.40	1.92	2.32	2.66	2.96	3.24	3.48	3.72	3.94	4.14	4.34
7.5	1.48	2.02	2.44	2.79	3.11	3.39	3.65	3.90	4.13	4.34	4.55
8.0	1.55	2.12	2.55	2.92	3.25	3.54	3.81	4.07	4.31	4.53	4.75
8.5	1.63	2.21	2.66	3.04	3.38	3.69	3.97	4.24	4.49	4.72	4.95
9.0	1.70	2.30	2.77	3.16	3.51	3.83	4.13	4.40	4.66	4.90	5.14
9.5	1.77	2.39	2.87	3.28	3.64	3.97	4.28	4.56	4.83	5.08	5.32
10	1.84	2.48	2.97	3.40	3.77	4.11	4.43	4.72	4.99	5.25	5.50
11	1.97	2.65	3.17	3.63	4.02	4.38	4.71	5.02	5.31	5.59	5.86
12	2.10	2.81	3.36	3.84	4.25	4.63	4.99	5.31	5.62	5.92	6.19
13	2.23	2.97	3.55	4.04	4.48	4.88	5.25	5.59	5.92	6.23	6.52
14	2.35	3.12	3.73	4.24	4.70	5.12	5.51	5.86	6.21	6.53	6.84
15	2.47	3.27	3.90	4.43	4.92	5.35	5.76	6.13	6.49	6.82	7.14
16	2.58	3.42	4.07	4.62	5.13	5.57	6.00	6.39	6.76	7.11	7.44

(Continued)

Table 10–5 (Con't.)

VELOCITY OF WATER IN FEET PER SECOND, BASED ON KUTTER'S FORMULA, COEFFICIENT OF ROUGHNESS

N = .030—Continued

$r = \frac{Area}{Wet\ Per.}$	$F = 3.168$ $S = .00060$	$F = 3.432$ $S = .00065$	$F = 3.696$ $S = .00070$	$F = 3.960$ $S = .00075$	$F = 4.224$ $S = .00080$	$F = 4.488$ $S = .00085$	$F = 4.752$ $S = .00090$	$F = 5.016$ $S = .00095$	$F = 5.280$ $S = .00100$	$F = 6.60$ $S = .00125$	$F = 7.92$ $S = .00150$
0.2	.28	.30	.31	.32	.33	.34	.35	.36	.37	.42	.46
0.4	.52	.54	.56	.58	.60	.62	.64	.66	.67	.76	.83
0.6	.72	.76	.79	.81	.84	.87	.89	.92	.94	1.06	1.16
0.8	.92	.95	.99	1.03	1.06	1.10	1.13	1.16	1.19	1.33	1.46
1.0	1.10	1.14	1.18	1.28	1.27	1.31	1.35	1.38	1.42	1.59	1.74
1.2	1.26	1.32	1.37	1.42	1.46	1.51	1.55	1.60	1.64	1.83	2.01
1.4	1.42	1.48	1.54	1.59	1.65	1.70	1.75	1.80	1.84	2.07	2.26
1.6	1.58	1.64	1.70	1.76	1.82	1.88	1.94	1.99	2.04	2.29	2.51
1.8	1.72	1.79	1.86	1.93	1.99	2.06	2.12	2.17	2.23	2.50	2.74
2.0	1.87	1.94	2.02	2.09	2.16	2.22	2.29	2.35	2.41	2.70	2.96
2.2	2.00	2.08	2.16	2.24	2.31	2.39	2.46	2.52	2.59	2.90	3.17
2.4	2.13	2.22	2.31	2.39	2.47	2.54	2.62	2.69	2.76	3.09	3.38
2.6	2.26	2.36	2.46	2.53	2.62	2.70	2.78	2.85	2.93	3.27	3.59
2.8	2.39	2.49	2.58	2.67	2.76	2.85	2.93	3.01	3.09	3.45	3.79
3.0	2.51	2.61	2.72	2.81	2.90	2.99	3.08	3.16	3.25	3.63	3.98
3.2	2.63	2.74	2.84	2.94	3.04	3.13	3.22	3.31	3.40	3.80	4.16
3.4	2.75	2.86	2.97	3.07	3.17	3.27	3.36	3.46	3.55	3.97	4.34
3.6	2.86	2.98	3.09	3.20	3.30	3.41	3.50	3.60	3.69	4.13	4.52
3.8	2.98	3.10	3.21	3.33	3.43	3.54	3.64	3.74	3.84	4.29	4.70
4.0	3.09	3.21	3.33	3.45	3.56	3.67	3.77	3.88	3.98	4.45	4.87
4.2	3.19	3.32	3.45	3.57	3.68	3.80	3.91	4.01	4.12	4.60	5.04
4.4	3.30	3.43	3.56	3.69	3.80	3.92	4.04	4.14	4.25	4.75	5.20
4.6	3.40	3.54	3.67	3.80	3.92	4.04	4.16	4.27	4.38	4.90	5.36
4.8	3.50	3.65	3.78	3.92	4.04	4.16	4.29	4.40	4.51	5.05	5.52
5.0	3.60	3.75	3.89	4.03	4.16	4.28	4.41	4.53	4.64	5.19	5.68
5.2	3.70	3.85	4.00	4.14	4.27	4.40	4.53	4.65	4.77	5.33	5.83
5.4	3.80	3.95	4.10	4.24	4.38	4.52	4.65	4.77	4.89	5.47	5.99
5.6	3.90	4.05	4.20	4.35	4.49	4.63	4.76	4.89	5.02	5.60	6.14
5.8	3.99	4.15	4.31	4.46	4.60	4.74	4.88	5.01	5.14	5.74	6.28
6.0	4.09	4.25	4.41	4.56	4.71	4.85	4.99	5.13	5.26	5.87	6.43
6.2	4.18	4.34	4.51	4.66	4.81	4.96	5.10	5.24	5.38	6.00	6.57
6.4	4.27	4.44	4.60	4.76	4.92	5.07	5.21	5.35	5.49	6.13	6.71
6.6	4.36	4.53	4.70	4.86	5.02	5.17	5.32	5.47	5.61	6.26	6.85
6.8	4.45	4.63	4.80	4.96	5.13	5.28	5.43	5.58	5.72	6.39	6.99
7.0	4.53	4.72	4.90	5.06	5.23	5.38	5.54	5.69	5.83	6.51	7.13
7.5	4.74	4.94	5.13	5.30	5.48	5.63	5.80	5.95	6.10	6.81	7.46
8.0	4.95	5.16	5.35	5.53	5.72	5.88	6.05	6.21	6.37	7.11	7.79
8.5	5.16	5.37	5.57	5.76	5.95	6.12	6.30	6.46	6.63	7.40	8.10
9.0	5.36	5.57	5.78	5.98	6.17	6.35	6.54	6.71	6.88	7.69	8.41
9.5	5.55	5.77	5.99	6.19	6.39	6.58	6.77	6.95	7.13	7.96	8.71
10	5.75	5.97	6.18	6.40	6.60	6.81	7.00	7.19	7.36	8.23	9.00
11	6.11	6.35	6.58	6.81	7.03	7.24	7.44	7.64	7.82	8.75	9.57
12	6.45	6.72	6.97	7.20	7.43	7.66	7.87	8.08	8.26	9.25	10.1
13	6.78	7.07	7.33	7.58	7.82	8.06	8.28	8.51	8.69	9.73	10.7
14	7.11	7.41	7.68	7.94	8.20	8.44	8.68	8.92	9.11	10.2	11.2
15	7.44	7.74	8.02	8.30	8.56	8.82	9.07	9.31	9.53	10.7	11.7
16	7.77	8.06	8.35	8.64	8.92	9.18	9.44	9.70	9.94	11.1	12.2

Table 10–5 (Con't.)

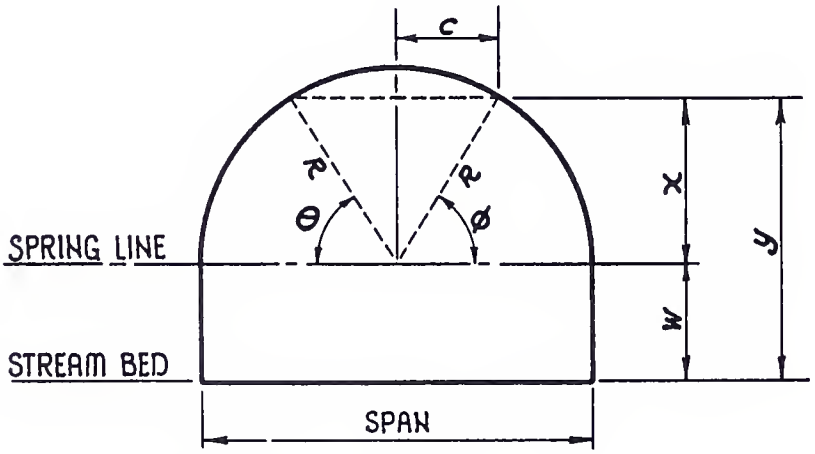
VELOCITY OF WATER IN FEET PER SECOND, BASED ON KUTTER'S FORMULA, COEFFICIENT OF ROUGHNESS

N = .030—Continued

$r = \frac{Area}{Wet\ Per.}$	F = 9.24 S = .00175	F = 10.56 S = .002	F = 15.84 S = .003	F = 21.12 S = .004	F = 26.40 S = .005	F = 52.80 S = .010	F = 31.68 S = .006	F = 42.24 S = .008
0.2	.50	.53	.65	.76	.85	.93	1.07	1.20
0.4	.90	.96	1.18	1.37	1.53	1.68	1.94	2.17
0.6	1.26	1.34	1.65	1.91	2.13	2.34	2.70	3.02
0.8	1.58	1.69	2.08	2.40	2.69	2.94	3.40	3.80
1.0	1.89	2.02	2.48	2.86	3.20	3.51	4.05	4.53
1.2	2.17	2.33	2.85	3.30	3.69	4.04	4.67	5.22
1.4	2.45	2.62	3.21	3.71	4.15	4.54	5.25	5.87
1.6	2.71	2.90	3.55	4.10	4.59	5.02	5.80	6.49
1.8	2.96	3.16	3.88	4.48	5.01	5.49	6.34	7.08
2.0	3.20	3.42	4.19	4.84	5.41	5.93	6.85	7.65
2.2	3.43	3.67	4.49	5.19	5.80	6.36	7.34	8.21
2.4	3.65	3.91	4.79	5.53	6.18	6.77	7.82	8.75
2.6	3.87	4.14	5.07	5.86	6.55	7.18	8.29	9.27
2.8	4.08	4.37	5.35	6.18	6.91	7.57	8.74	9.77
3.0	4.29	4.59	5.62	6.49	7.26	7.95	9.18	10.3
3.2	4.50	4.81	5.89	6.80	7.60	8.32	9.61	10.7
3.4	4.70	5.02	6.14	7.09	7.93	8.69	10.0	11.2
3.6	4.89	5.22	6.38	7.38	8.25	9.04	10.4	11.7
3.8	5.08	5.42	6.64	7.67	8.57	9.39	10.8	12.1
4.0	5.26	5.62	6.88	7.95	8.88	9.73	11.2	12.6
4.2	5.44	5.81	7.12	8.22	9.19	10.1	11.6	13.0
4.4	5.62	6.00	7.35	8.49	9.49	10.4	12.0	13.4
4.6	5.79	6.19	7.58	8.75	9.78	10.7	12.4	13.8
4.6	5.96	6.38	7.80	9.01	10.1	11.0	12.8	14.2
5.0	6.13	6.56	8.02	9.26	10.4	11.3	13.1	14.6
5.2	6.30	6.73	8.24	9.51	10.6	11.7	13.5	15.0
5.4	6.47	6.91	8.46	9.76	10.9	12.0	13.8	15.4
5.6	6.63	7.08	8.67	10.0	11.2	12.3	14.1	15.8
5.8	6.79	7.25	8.87	10.3	11.5	12.5	14.5	16.2
6.0	6.94	7.42	9.08	10.5	11.7	12.8	14.8	16.6
6.2	7.10	7.58	9.28	10.7	12.0	13.1	15.1	16.9
6.4	7.25	7.75	9.48	11.0	12.2	13.4	15.5	17.3
6.6	7.40	7.91	9.67	11.2	12.5	13.7	15.8	17.6
6.8	7.55	8.08	9.87	11.4	12.7	14.0	16.1	18.0
7.0	7.70	8.24	10.1	11.6	13.0	14.2	16.4	18.3
7.5	8.05	8.62	10.6	12.2	13.6	14.9	17.2	19.2
8.0	8.40	9.00	11.0	12.7	14.2	15.5	17.9	20.3
8.5	8.74	9.38	11.5	13.2	14.8	16.2	18.6	20.8
9.0	9.08	9.74	11.9	13.7	15.3	16.8	19.3	21.6
9.5	9.40	10.1	12.3	14.2	15.9	17.4	20.0	22.4
10	9.72	10.4	12.7	14.7	16.4	17.9	20.7	23.1
11	10.3	11.1	13.5	15.6	17.4	19.1	22.0	24.6
12	10.9	11.7	14.3	16.5	18.4	20.1	23.3	26.0
13	11.5	12.2	15.0	17.3	19.4	21.2	24.5	27.3
14	12.0	12.9	15.7	18.1	20.3	22.2	25.6	28.6
15	12.6	13.5	16.4	18.9	21.2	23.2	26.8	29.9
16	13.1	14.1	17.1	19.7	22.0	24.1	27.8	31.1

Figure 10–1

METHOD FOR CALCULATING EFFECTIVE AREA OF WATERWAY OPENING AND WETTED PERIMETER OF STANDARD SEMICIRCULAR ARCHES



(R) RADIUS = SPAN ÷ 2

CLEAR = R + (W) SIDEWALL

$Y = 0.9 \times (R + W)$

$X = Y - W$

$\text{SINE } \phi = \frac{X}{R}$

$(\theta = \phi)$

$$\text{AREA SECTORS} = \frac{\theta + \phi}{360} \times R^2 \times 3.1416$$

$$C = \sqrt{R^2 - X^2}$$

AREA TRIANGLE = C × X

TOTAL AREA WATERWAY = (SPAN × W) + (AREA SECTORS) + (AREA TRIANGLE)

WETTED PERIMETER = SPAN + 2W + [(θ + φ) × R × 0.01745]

Table 10–6

WATERWAY DATA FOR STANDARD SEMICIRCULAR ARCHES

Radius of Intrados = ½ Span
Opening Considered Flowing 9/10 Full

Span	Clear	Net Area	Wetted Perimeter	Hydraulic Radius
6′	3.5′	16.48°′	13.50′	1.22
	4.	19.32	14.28	1.35
	4.5	22.18	15.08	1.47
	5.	25.02	15.90	1.57
	5.5	27.84	16.72	1.67
	6.	30.67	17.55	1.75
8′	4.5	28.02	17.73	1.58
	5.	31.81	18.52	1.72
	5.5	35.62	19.31	1.84
	6.	39.42	20.12	1.96
	6.5	43.21	20.93	2.06
	7.	46.98	21.75	2 16
	7.5	50.74	22.58	2.25
	8.	54.51	23.41	2.33
10′	5.5	42.58	21.96	1.94
	6.	47.35	22.75	2.08
	6.5	52.10	23.54	2.21
	7.	56.85	24.34	2.34
	7.5	61.59	25.15	2.45
	8.	66.33	25.96	2.56
	8.5	71.05	26.78	2.65
	9.	75.77	27.60	2.75
	9.5	80.48	28.43	2.83
	10.	85.18	29.26	2.91
12′	6.5	60.18	26.20	2.30
	7.	65.92	26.98	2.44
	7.5	71.57	27.77	2.58
	8.	77.29	28.56	2.71
	8.5	83.00	29.37	2.83
	9.	88.70	30.18	2.94
	9.5	94.39	30.99	3.05
	10.	100.07	31.80	3.15
	10.5	105.71	32.62	3.24
	11.	111.34	33.45	3.33
	11.5	117.01	34.28	3.41
	12.	122.66	35.11	3.49
14′	7.5	80.74	30.43	2.65
	8.	87.48	31.21	2.80
	8.5	94.11	32.00	2.94
	9.	100.82	32.79	3.07
	9.5	107.43	33.59	3.20
	10.	114.1–	34.39	3.32
	10.5	120.72	35.20	3.43
	11.	127.31	36.02	3.53
	11.5	133.99	36.83	3.64
	12.	140.55	37.65	3.73
	12.5	147.22	38.47	3.83
	13.	153.77	39.30	3.91
	13.5	160.42	40.13	4.00
	14.	166.96	40.96	4.08

Span	Clear	Net Area	Wetted Perimeter	Hydraulic Radius
16′	8.5	104.43	34.67	3.01
	9.	112.08	35.45	3.16
	9.5	119.73	36.23	3.30
	10.	127.30	37.02	3.44
	10.5	134.86	37.82	3.57
	11.	142.47	38.62	3.69
	11.5	150.08	39.42	3.81
	12.	157.68	40.23	3.92
	12.5	165.27	41.04	4.03
	13.	172.86	41.86	4.13
	13.5	180.43	42.68	4.23
	14.	187.93	43.49	4.32
	14.5	195 42	44 32	4.41
	15.	202.98	45.14	4.50
	15.5	210.52	45.98	4.58
	16.	218.07	46.81	4.66
18′	9.5	131.09	38.93	3.37
	10.	139.68	39.55	3.53
	10.5	148.26	40.49	3.66
	11.	156.83	41.28	3.80
	11.5	165.40	41.92	3.95
	12.	173.96	42.87	4.06
	12.5	182.49	43.67	4.18
	13.	191.04	44.48	4.30
	13.5	199.56	45.29	4.41
	14.	208.08	46.10	4.52
	14.5	216.61	46.91	4.62
	15.	225.11	47.73	4.72
	15.5	233.61	48.55	4.81
	16.	242.09	49.38	4.90
	16.5	250.59	50.20	4.99
	17.	259.05	51.03	5.08
	17.5	267.53	51.86	5.16
	18.	275.99	52.69	5.24
20′	10.5	160.77	43.17	3.71
	11.	170.32	43.95	3.88
	11.5	179.85	44.73	4.02
	12.	189.38	45.52	4.16
	12.5	198.90	46.31	4.29
	13.	208.42	47.10	4.43
	13.5	217.92	47.90	4.55
	14.	227.41	48.71	4.67
	14.5	236.90	49.51	4.78
	15.	246.38	50.32	4.90
	15.5	255.84	51.13	5.00
	16.	265.31	51.95	5.11
	16.5	274.76	52.76	5.21
	17.	284.21	53.58	5.30
	17.5	293.64	54.40	5.40
	18.	303.08	55.23	5.49
	18.5	312.50	56.05	5.58
	19.	321.92	56.88	5.66
	19.5	331.33	57.71	5.74
	20.	340.73	58.55	5.82

10–33 Method for calculating effective area of waterway opening and wetted perimeter of standard semicircular arches.

(A) In order to properly select a design for a structure at a particular site, it is necessary to know the kind and the depth of the materials which will support the substructure, and to know the nature of the materials which must be passed through in order to reach proper foundations. This information is obtained by explorations.

(B) Explorations are generally carried out by means of excavated pits, driven rods, driven pipes, or core borings.

(C) The method of exploration to be used is dependent upon how much knowledge is available for the site, the depth to which the exploration is to be carried, and the type and magnitude of the contemplated work.

(D) Failure to make the proper foundation tests in advance of selecting the design of structure, which should be placed at a particular location, has resulted in needless expense.

(E) Data concerning driven wells, shafts, quarries, or other subsurface work located in the immediate vicinity, often furnish useful information but it should be borne in mind that explorations made a very few feet apart may show great variations in subsurface conditions.

(F) Excavated pits, shored if necessary, made by hand or with mechanical equipment, furnish the most satisfactory subsurface information, and they should be utilized where practicable. When a rock or hard stratum is reached, it should be explored for thickness by drilling or core boring methods. It is desirable to penetrate it several feet, so as to be sure that it has sufficient thickness to carry the desired loads and is not a boulder or a thin stratum of stone with a soft pocket beneath.

(G) Core borings, in general, provide fairly satisfactory data. This method should be used where excavated pits are not practicable or considerable depth is required to be explored. Such work may be performed by contract.

(H) Data procured by driving rods or pipe, is generally satisfactory for relatively small structures. Boulder, coarse or compact gravel, and rock formations prohibit their use when accurate data is required.

(I) When results obtained do not seem consistent, additional tests must be made in the vicinity of the questionable location, and the new sites shall be located and referenced on the drawings.

(J) Earth samples shall always be taken when excavated pits or pipe are used, and samples and cores when core borings are specified. The earth samples shall be placed in glass containers.

(K) The proper method, number, and depths for exploration shall be determined. The sites for tests shall be located and referenced on the drawings.

(L) After the necessary approvals for the type of explorations have been obtained, the sites shall be located by stakes on the project.

(M) At least one inspector, thoroughly familiar with the type of work, must be assigned to a project to see that proper procedure is followed and all procurable data is obtained. An inspector shall be assigned to each two (2) core drilling machines.

(N) The inspectors shall remain on the project at all times during the making of tests and shall keep an accurate record of all data and shall see that all soil samples and cores are properly boxed, and the boxes stored in a suitable and safe place or hauled and shipped to the designated destination.

(O) When explorations are made by contract, the inspectors shall see that the following data is obtained by the contractor and that he records same in a book and on tracing cloth.

1. Elevations of ground at location of all tests and referenced to survey data.
2. Elevation for top of each different material penetrated.
3. Elevation for top of each stratum of rock encountered.
4. Elevation of the bottom of core.
5. Elevation of ground water where encountered.
6. The number of blows of the hammer per foot of penetration shall be recorded for the entire depth of test or until rock is encountered.
7. The weight of the hammer.
8. The drop of the hammer, in feet.
9. Earth shall be described and recorded in accordance with the following classifications:
   a. Kind: Top soil, loam, clay, sandy, gravelly, or similar designation.
   b. Color: Light, medium, dark and color type.
   c. Moisture: Dry, moist, wet or very wet.
   d. Compaction: Loose, medium, compact or stiff.
   e. Percentage recovered. (If casing is used.)
10. Rock shall be described and recorded in accordance with the following classifications:
    a. Shale, slate, limestone, sandstone or similar designation.
    b. Hardness: Broken, soft, medium, hard or very hard.
    c. Percentage recovered. (Equals amount of material of core divided by length of drill casing.)

(P) Any data which may furnish information relative to the material at a site should be recorded. (Such as bearing power, or a one hundred (100) foot truss bridge in place fifty (50) years on same type of material two hundred (200) feet upstream, with foundations on timber, or placed five (5) feet below stream bed, or spread footing construction, mentioning the condition of the foundations for this construction.)

(Q) Care must be exercised in taking earth samples and placing them in glass containers with the proper identification as soon as the samples are taken.

(R) Each glass container shall be marked by a label with the following information:

1. Route, section and county.

2. Number of test hole, station location, and right or left of center line.
3. Elevations or depths represented by sample.
4. Kind of material.

(S) The glass containers shall be placed in substantial wooden boxes, in sequence. When rock cores are taken, the glass containers and rock cores shall be placed in substantial wooden core boxes, in sequence, and a record of depth shall be shown on the partition of the boxes.

(T) The top of all boxes shall be plainly marked with the route, section, county, stations, and the numbers of the test holes.

(U) When explorations are made by Department forces, the same procedure shall be followed, except that data obtained for small structures may be placed on forms similar to the two (2) following types and be shown on the road drawings:

(V) The tracing prepared by the contractor or the district office, and copies of all data, shall then be forwarded with the road drawings, and Forms 444 when required, to the Central Office. Samples and cores shall be stored at the district maintenance shed of the county wherein the samples and cores were taken.

(W) The district engineer shall forward his recommended elevations for bottoms of structure footings.

(X) Field notes should be reviewed carefully so as to make sure that they contain all the information necessary for the accurate plotting of the bridge site, obstructions and all other pertinent details, so that anyone who is not familiar with the local conditions may, from the submitted drawings and sections, secure all the data and information required to properly locate, plan, and design the necessary structures.

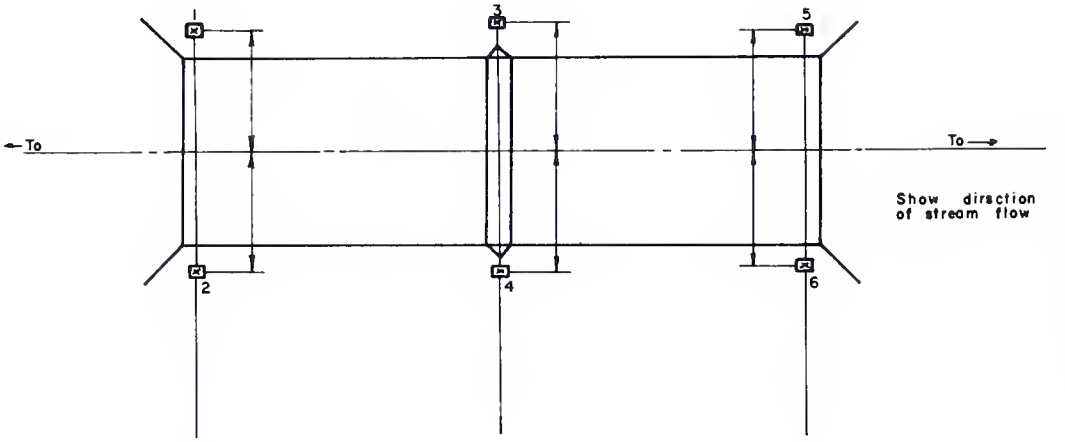
(Y) The procuring of accurate data requires conscientious effort on the part of each individual concerned and it must be complete in order to show the actual conditions for each particular site.

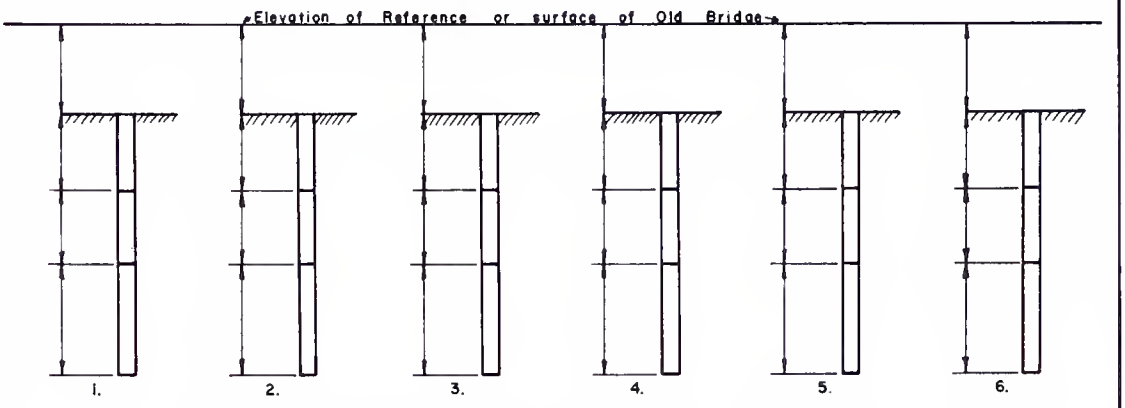
Figure 10–2

TEST HOLES FOR BRIDGE FOUNDATIONS

(Use for small Bridges.)

Route _____ County _____ Sta. _____





Show depth and describe each kind of material in each hole.

Distance from reference mark to Water Surface _____ To Stream Bed _____

Water clear _____ Sulphur _____ Remarks. _____

_____

Costs:

_____ Hrs. Foreman at _____ = _____

_____ Hrs. Labor at _____ = _____

_____ Hrs. Equipment at _____ = _____

Supplies = _____

Total =

_____
Foreman

_____
Asst. Supt.

_____
Supt.

Date - _____

(Two Copies - One for Supt. - One for Dist. Engr.)

Figure 10–3

FOUNDATION TEST BORINGS

Borings Drilled by _____ District _____

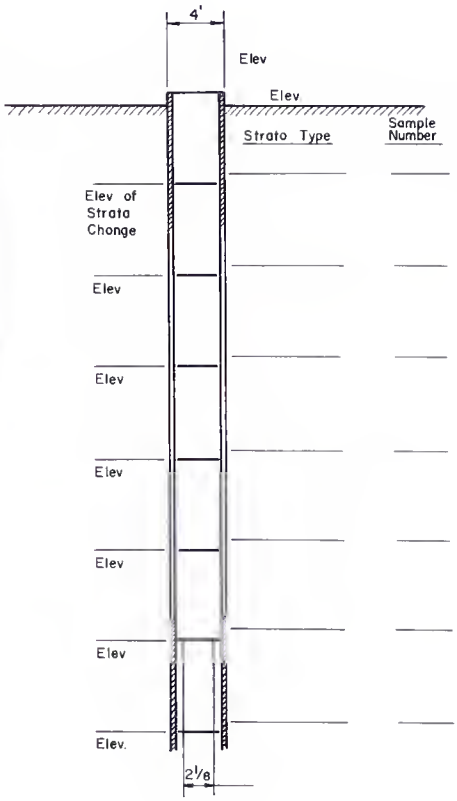
Inspector _____ Route _____ Co. _____

Date Started Drilling _____ Time _____ Sta _____ Ft. _____ Rt. Lt. of ℄

Date Completed _____ Time _____ Test Hole No. _____

Penetration (Elev. of Last Blow Shown)

Blows	Weight	Fall	Penetration Total	Per Blow	Elev



Elev Top of Hole – _____

Elev. Bot. of Hole – _____

Depth of Hole – _____ Ft

Sample Number	Elev

Ground Water encountered at – _____

Checked by _____ Date _____ Elev. 4" Casing – Begin – _____ End. – _____

Constr. Engr. _____ Elev 2⅛" Diam. Drill – Begin – _____ End – _____

Draftsman _____

(Inspector shall make this report on tracing paper)

Table 10–7

TABLE OF SIZES AND WEIGHTS FOR CORRUGATED METAL PIPE-ARCHES

(All dimensions measured from inside crests.)

Gauge	*Span* Inches*	*Bias* Inches*	*Waterway† Area (Sq. Ft.)*	*Pipe of Equal Periphery in Inches*	*Approximate Weight lbs. per Foot of Length*	
						Asbestos-Bonded
					Galvanized	*Paved Invert*
16	18	11	1.1	15	12.9	22
16	22	13	1.6	18	15.3	26
14	29	18	2.8	24	25.2	38
14	36	22	4.4	30	30.9	48
12	43	27	6.4	36	51.0	72
12	50	31	8.7	42	59.5	84
12	58	36	11.4	48	68.0	95
12	65	40	14.3	54	77.8	108
10	72	44	17.6	60	108.7	143

Notes—* A variation of 1 inch in span and rise is permissible.

† The end area of pipe-arches is not to be compared directly with that of circular pipe due to different hydraulic characteristics. The pipe-arch is hydraulically a more efficient structure. In using Talbots' formula, use end-area values of pipe of equal periphery. For example, if a drainage situation calls for an end-area of 5 sq. ft., use a 36 x 22 inch pipe-arch because its capacity is equal to or greater than a 30-inch round pipe (of equal periphery).

10–34 BRIDGE SITE TRIANGULATION

(a) Consultants will be required to establish a first-order triangulation net at each structure site where the total span distance between abutments will be 600 feet or more.

(b) The error of closure in length for any net shall not exceed 1 part in 25,000. The actual error of the baseline measurement shall not exceed 1 part in 300,000.

(c) Angles shall be turned with a minimum of four (4) direct and four (4) reverse readings. Angular closure of a triangle shall not exceed specifications contained in Table 9–2, Triangulation—Classification and Standards of Accuracy published in Chapter Nine of this Manual.

(d) Permanent monuments, approved by the District Engineer, will be established on each side of the proposed structure to form the required base-lines. These monuments shall be readily accessible for the establishment of abutment and pier locations.

(e) Base-lines shall not be less than one-third (1/3) the proposed length of structure. This procedure will tend to eliminate small angles which result in decreased accuracy. Terrain may necessitate a change to this rule, however, any proposed deviation shall be approved by the District Engineer.

(f) Locations of abutments and piers will be set by the consultant engineer utilizing the procedure specified by the responsible District Engineer.

10–35 BRIDGE SITE TRILATERATION

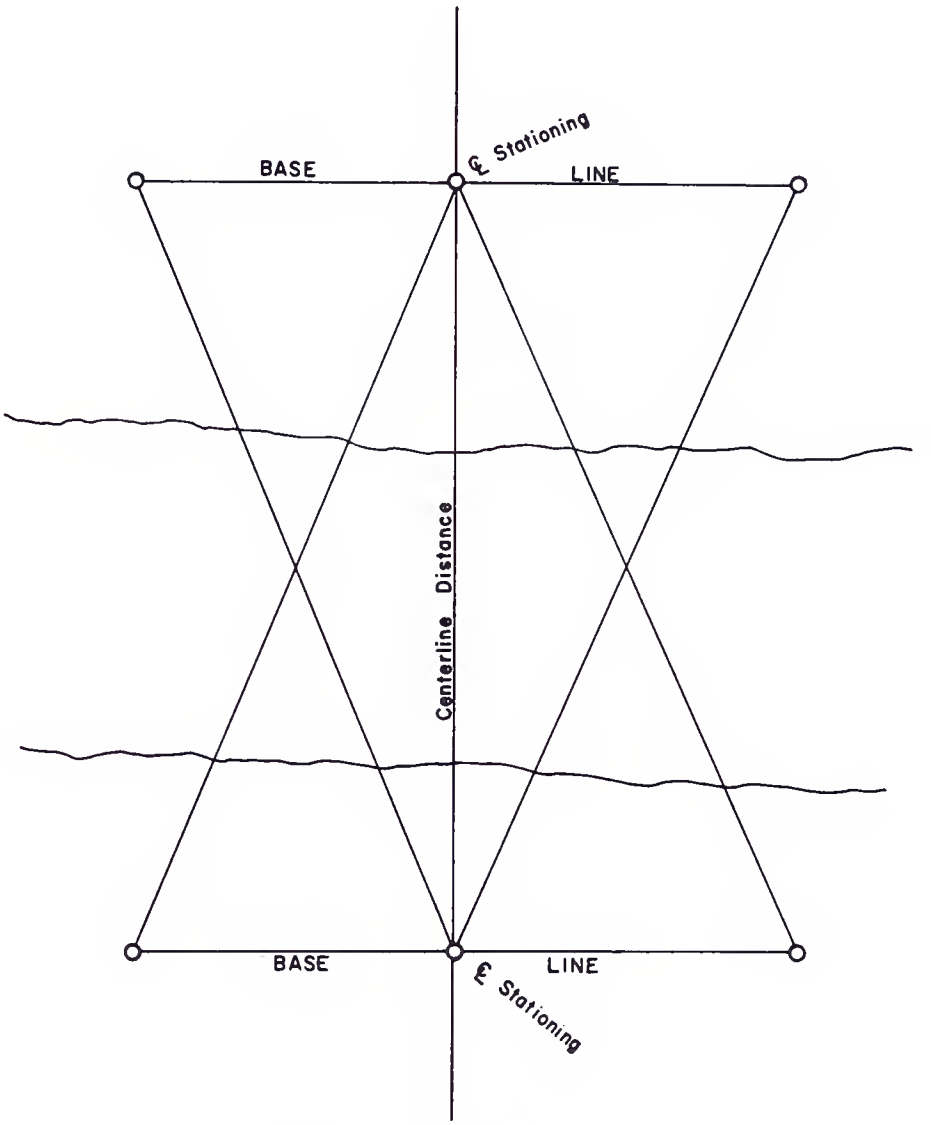
(a) Consultants may establish a first-order trilateration nets, in lieu of a triangulation net, at a structure site upon approval of the District Engineer.

(b) A distance measuring system utilizing the propagation of **light waves** is the only acceptable instrument to the Department for this work.

(c) Closures for all trilateration work will be equal to closures required for first-order triangulation.

Figure 10–4

EXAMPLE OF BRIDGE SITE TRIANGULATION NET



NOTE: O = Permanent Monument

Table ____

CHAPTER ELEVEN

CONSTRUCTION SURVEYS

11–1 All construction work performed by a contractor is governed by the lines and grades established by a construction survey made by a corps or by the inspector-in-charge of a project, and by the Specifications, drawings, and Special Requirements of the contract.

11–2 Construction survey work involves re-establishing the points and lines of the preliminary or later survey when necessary; placing sufficient stakes, properly marked to lay out and adequately control the construction operations, and making and properly recording all notes and survey records in connection therewith. The construction survey should furnish the contractor and the inspector with sufficient information and stakes to assure the construction of the highway and its appurtenances in accordance with the drawings, Specifications, and Special Requirements.

11–3 When possible a construction survey should be completed and the grade sheets prepared before the contractor starts operations. When practical, the inspector to be assigned in charge of the project should be placed on the project when the corps starts in order to become thoroughly familiar with the stakeout and all details of the proposed construction.

11–4 Notebooks.

(1) The construction survey notebooks shall be prepared and the notes identified in accordance with the instructions under Chapter Fifteen, of this Manual. No changes shall be made in the preliminary survey notebooks, however any errors or discrepancies found in the preliminary survey notes, or on the drawings, shall be noted in both the preliminary and construction notebooks and called to the attention of his superiors, by the chief-of-party. When there has been an office change made on the drawings, the new line shall be run in and if necessary new cross-sections taken and proper notations made in both preliminary and construction survey notebooks.

11–5 Center Line.

(1) The chief-of-party shall examine the field notes of the preliminary survey, the drawings, and the Special Provisions of the contract, so that he may become thoroughly familiar with the proposed work, the difficulties involved in the location and design, and any changes made in the line since the preliminary or subsequent surveys were made. The survey party shall then locate the original points of tangency and curvature on the ground from the original notes. If any office changes appear on the drawings, they shall be run in and the points of curvature and tangency staked and referenced to at least three permanent objects outside the construction area. The notes shall show such relocations as laid out and its relation to the original center line.

(2) When such line changes have been made, the center line equation shall be compared with that shown on the drawings. Either new cross-sections must be taken on the line change or the offset distances between the original center line from which the preliminary cross-sections were taken and the line change, computed at the location of each cross-section.

(3) All reference points shall be checked and if any have been disturbed or destroyed, or if there is danger that they may be disturbed by the construction, new references should be placed outside the construction area, and properly described and noted in the notebook. The construction center line should be established over the entire project, if possible, before any work is done. This will enable the chief-of-party and the inspector-in-charge to pick up a point on the center line at any location and also view the project as a whole before any work starts.

(4) When the construction survey cannot be completed before the contractor starts operations, the inspector-in-charge shall secure from the contractor his plan of operation and the information as to where he wishes to commence operations, and the chief-of-party shall arrange his work so as to supply the contractor with sufficient stakes and information in order that the work will not be delayed.

11–6 Bench Marks.

(1) Bench levels should be run and the bench marks checked for location and elevation. Any that have been destroyed or damaged, or that will be disturbed by new construction, should be re-established or replaced in locations where they will not be disturbed. All information on re-established bench marks should be kept in the notes and marked on the set of plans used by the survey corps and both the inspector-in-charge and the district drafting room informed.

11–7 Construction Stakes.

(1) "Construction stakes are to be placed at right angles to the center line on tangents and on radial lines on curves. They are to be set at fifty foot stations and all control points such as a P.C., P.T., central P.O.C., and P.O.T. shall be referenced with three hubs and guards. Construction stakes shall be defined as a hub driven flush with the ground and a guard stake in back of the hub identifying the station and offset from center line. The hub shall have a transit tack placed in the top to denote the exact location of offset and elevation. Construction stakes shall be placed beyond the limits of construction and inside the right-of-way when possible. It is advisable to place the stakes on a parallel line on tangents, and possibly on curves, if the terrain and topographic features will not cause a costly delay in time. A hub protruding out of the ground is easily destroyed and subject to frost heave much more than if flush with the ground."

(2) When deemed necessary on sharp horizontal curves, stakes shall be placed at intervals of twenty-five (25) feet or less. On grades of more than four (4) percent an offset stake shall be set on each side of each designated grade point. When the top of cut slopes or the toe of embankments are more than six (6) feet vertically above or below the finished grade line, slope stakes shall be placed. The rounding of slopes in cut sections shall be disregarded in the placing of slope stakes, and stakes shall be placed

at the intersection of the normal theoretical slope line with the present ground line and all parties so informed. Limit of slope stakes may be placed for the rounding of slopes.

(2) Stakes used on a construction survey should be so placed as to be well beyond the limits of construction, so the stakes can be referred to during construction, and be available when the final survey is made. Construction stakes should be driven vertically, flush with the ground for protection, and with a guard stake to show station identity and offset from center line.

11–8 Grade Sheets.

(1) Levels shall be run over these offset stakes to the nearest one-hundredth (0.01) of a foot and the elevations checked against the bench marks throughout the project. The grade sheets shall carry the proper identification at the top of Form 413, the date prepared and the number of the book from which the stake elevations and distances are copied. The chief-of-party shall compute and check the stake elevations in the field and forward the notebook to the district office without delay. Generally the district office will prepare the grade sheets. The plans engineer shall have the field computations re-checked and then prepare the Grade Sheets, Form 413, being careful not to reverse right and left stakes. Under the two columns "Distance from Top of Stake to Finished Grade, Above—Below," the elevation of finished grade is determined from the stake in the field and the "Above" column should include the plus (+) or vertical distances when the finished grade line is above the elevation given for the stake, conversely, when the finished grade line is below the elevation given for the stake, the vertical distance should be shown in the "Below" or minus (−) column. When the grade sheets have been checked and completed, sufficient prints shall be made for the use of the contractor and inspectors.

(2) When the construction survey has been delayed and the contractor is working it may be necessary for the chief-of-party to prepare grade sheets in the field so as not to delay the contractor's operations. In this case, the chief-of-party shall prepare three (3) copies of the grade sheets and have them checked by the inspector-in-charge. One copy shall be given to the contractor, one to the inspector-in-charge, and one copy forwarded to the district office, together with the notebook. The plans engineer shall prepare grade sheets in the regular manner and forward sufficient prints to the field with a letter advising the inspector-in-charge that the grade sheets prepared in the field were found to be correct, otherwise noting any discrepancies found, which shall be immediately corrected in the field.

(3) When stakes are replaced in the field the plans engineer shall have new grade sheets prepared for the section affected and forward prints to the field, with a notation they supersede the previous grade sheets between certain stations prepared on a certain date. The inspector-in-charge shall cross out, or void the data superseded on all copies of the original grade sheets.

11–9 Construction Cross-Sections.

(1) It is essential that accurate cross-sections be secured within the area of the proposed improvement before the contractor starts grading operations. If those taken during the preliminary survey still show the true conditions

they may be used without further work; however, if there has been any change in the contour of the ground surface, if the original cross-sections were taken during the winter months and there is a general change due to frost or ice action, or if decided line changes have been made, construction cross-sections shall be taken before the contractor starts operations. The design may also necessitate new or additional cross-sections. Care shall be observed to take necessary profiles and cross-sections where side roads and approaches are to be constructed, or additional cross-sections taken to include areas where structures, special ditches or channel changes are to be made. Prints of construction cross-sections shall be forwarded to the field as soon as possible.

11–10 Stakes for Special Structures.

(1) Special structures shall be staked well ahead of actual grading operations, so the contractor may perform such work as building culverts, drains, sewers and like structures as early as possible to permit adequate settlement of the backfill. Ordinarily the inspector-in-charge will be able to set construction stakes, for ditches, pipe culverts and other miscellaneous excavation, and the corps will not stake such structures or ditches unless directed. The survey corps shall set stakes for large culverts, box culverts, channel changes, and all bridges.

11–11 U.S.C. & G.S. Bench Marks.

(1) U.S.C. & G.S. bench marks are established as a permanent record and extreme care must be exercised when they are encountered, to preserve their value. If possible, they shall not be disturbed until permission to do so has been obtained.

(2) When a chief-of-party finds it will be necessary to move a U.S.C. & G.S. bench mark, he shall immediately notify the district office and furnish a complete description with a sketch showing the data inscribed on the head of the bench mark. The district office shall immediately write to the "Director, U. S. Coast and Geodetic Survey, Washington, D. C.," who will furnish a new disc and instructions for placing and recording. As the new bench mark will probably not be installed until after it has become necessary to remove the old one, a temporary bench mark shall be established on some permanent object by running duplicate levels to avoid error in transfer. The level readings shall be carried to three (3) decimal places in order to preserve the accuracy of the elevation.

11–12 Bridge Site, Construction Stakeout.

(1) The true center line of the bridge shall be staked. The stationing shall be carried from one accurately determined station at least one hundred (100) feet from the bridge, to an accurately determined station on the other side of the bridge at least one hundred (100) feet distant. The structure shall be exactly located as shown on the drawings, and the bridge stakeout sheets furnished by the district office.

(2) The establishment of the center line and the stationing of the structure shall be checked in sufficient detail to make absolutely sure of its correct location. After work has started, the position cannot be adjusted without considerable cost and lost time. The center line of the bridge shall be care-

fully monumented by driving hubs at each side of the structure, well outside of the construction area. When possible a back sight shall be set on the line so that in case the sight is blocked over the structure by forms, the center line can always be determined. These center line hubs shall be tacked and referenced to objects that are not to be disturbed during the construction.

(3) The face of abutments, center line of piers, outside line of parapets, and other needed working lines, shall be referenced by at least two stakes on each side of the bridge. The face line of the wings shall be run and referenced by at least two stakes. All stakes shall be protected by the contractor in an approved manner. When the face of abutment is battered the line of the top of abutment shall be staked. The notes shall show the location of all stakes on a carefully drawn sketch, or on forms furnished by the Department.

(4) The district bridge engineer shall furnish the inspector-in-charge with all elevation and measurements necessary for the construction of the structure.

11–13 Spiral Curves.

(1) Normally, on a spiral curve, it is advisable that the chief-of-party refer to the tables and computations as given in the handbook, "Transition Curves for Highways," as published by the United States Department of Agriculture. However, if the spiral is designed in the office and imposed on a plan as a construction center line, it is easier to compute the offsets from the simple curve than establish the spiral on its own center line. This is applicable to a simple curve with spirals at each end. First establish the simple curve center line. Establish the T. S., S. C., C. S., and S. T.

EXAMPLE Given: L S. = 300.00 feet, P = 1.63. Then the offset from the survey center line will increase from 0.0 feet at T. S., to 1.63 feet at S. C., and increase the same amount from the S. T. to the C. S. Using a spiral of 300.00 feet with a P distance of 1.63 feet, we find the offset will increase .005433 feet per foot in length along survey center line. Each 50.00 foot station will offset .271665 feet more than the preceding 50.00 foot station. If there is a structure on the spiral, it may be necessary to run the construction center line. These computed offsets will then be added to, or subtracted from, the offsets measured from the survey center line to construction stakes. From the S. C. thru C. S., the full 1.63 feet will be used as a correction.

CHAPTER TWELVE

BORROW PIT SURVEYS

12–1 No borrow pit shall be staked or cross-sectioned until the site and material has been approved by either the district construction engineer or the assistant district construction engineer. The approximate amount of borrow needed shall be determined prior to the staking in order to determine the approximate limits of the borrow pit. The site of the borrow pit must be cleared, grubbed, and stripped of all sod and other unsuitable materials before the cross-sections are taken.

12–2 In staking borrow pits a base line shall be established well outside the limits of the borrow to be taken and on this base line stakes shall be driven flush with the ground and protected by guard stakes so that they will not be disturbed after the final cross-sections are taken. These stakes shall be placed at each point where the contour of the ground changes and in no case shall they be more than twenty-five (25) feet apart. A second base line shall then be established, running parallel to the original, and well beyond the limits of the proposed borrow pit so that the pit will lie between these two lines. This second base line shall then be staked so that each stake will be directly opposite the corresponding stake in the original base line. These base lines shall be straight and without any angles or turns. The end stakes of both base lines shall be referenced and a sketch made in the notebook showing the staking diagram. The chief-of-party shall exercise good judgment in staking out these base lines in order to show the true contour of the surface of the borrow pit to best advantage.

12–3 Baselines for all borrow pits shall be tied or referenced to a construction center line if the center line is within a reasonable distance. Use of this procedure will serve as a reference for finals and will aid the draftsman to differentiate between two or more borrow pits and the center line areas. Borrow pits are sometimes enlarged after the original layout and field notes have been completed. Referencing the original base line to the center line will aid in re-establishing the baseline should it be destroyed by enlargement of the pit.

12–4 A bench mark shall be established near the site of the borrow pit, preferably on the same datum governing the project, however, if an assumed datum is used two bench marks shall be established, one at either end of the borrow pit at locations where they will not be disturbed. Elevation and check levels shall be taken on the tops of all stakes and accurate cross-sections shall then be run between the corresponding stakes of the two base lines.

12–5 All breaks in the contour of the ground shall be shown and the measurements, both for distance and elevation, must check between the corresponding stakes. Where a borrow pit is located adjacent to the roadway, the preliminary roadway cross-sections must be extended to cover its limits, and such additional sections shall be taken as are deemed necessary, but at not more than twenty-five (25) foot intervals. In cases of this nature, where the center line of the roadway

is a tangent, a base line parallel to the roadway center line shall be established similar to the manner above described in order to insure the final cross-sections being taken at the same points as the preliminary cross-sections. Where the roadway center line is not a tangent, no parellel base line shall be established.

12–6 It shall be the duty of the inspector-in-charge to see that the excavation in the borrow pit is confined to the area cleared and cross-sectioned, and if it becomes necessary to extend the limits of the borrow pit, the cross-sections shall be extended before the additional borrow excavation is taken.

12–7 Final cross-sections shall be taken after all borrow excavation is completed. All irregularities in the contour of the pit must be indicated. The final cross-sections must be run for the entire distance between the opposite stakes on each base line and must check for elevation and distance. Final cross-sections must always be taken at each limit of the excavated portion of the borrow pit even though a preliminary cross-section was not taken at that location. Care shall be exercised in taking final sections to show any waste material that may be rolled up by the shovel at the edges of the pit. All material (excepting sod and other objectionable materials removed prior to the original cross-sectioning of the pit) excavated from within the confines of the pit and wasted as unsuitable material shall be measured as a solid, if the site of the waste disposal is not covered by preliminary cross-sections.

12–8 Boulders encountered in the excavation of the borrow pit and not used in the roadway embankment must be compactly piled, measured as a solid, and measurements recorded in the field notebook so that this quantity may be deducted from the borrow excavation quantities.

12–9 Before taking final cross-sections the bottom of the pit should be leveled off and the sides smoothed up and left in a presentable condition.

12–10 A sketch of the borrow pit layout should be shown preceding the notes, giving the owner's name and address and located with reference to stations on the center line of the new construction or otherwise so as to be readily found. The location of reference stakes, distances between base lines, starting and ending of cross-sections along the base line, and location and description of bench marks should also be shown. If there is more than one borrow pit, they should be serially numbered for estimating purposes.

CHAPTER THIRTEEN

FINAL SURVEYS

13–1 GENERAL. A final survey is made of a project to determine the payable excavation, paving and miscellaneous items and also to show graphically the location of the road in relation to the center line and elevations as given on the drawings.

13–2 ALIGNMENT. In making the final survey it is of the utmost importance that the preliminary survey line be reproduced accurately, including all stations and intermediate plusses shown in the preliminary notes. If due to the development of an office relocation or for some other reason, a construction survey has been made and new cross-sections taken, it will be necessary to reproduce the construction line in its entirety. The notebooks of the preliminary survey and the construction survey, together with the drawings, shall be examined to determine the alignment used in the construction. The location of all stations and intermediate plusses on the preliminary or the construction center line, as the case may be, shall be accurately marked on the pavement with paint, using an encircled dot, so the cross-section party will have no difficulty in locating these points, and also for purposes of checking, should any discrepancies arise during the plotting of the final survey notes. P. C.'s, P. T.'s, P. O. T.'s and P. I.'s, if the latter falls on the pavement, should be marked with a painted "X" surrounded by a circle and the stational plus also shown on the pavement in paint

13–3 CHAINING SURVEY AND PAVEMENT CENTER LINES: Two methods of chaining are used on the final survey. Horizontal survey center line chaining, and pavement center line surface measurement.

A. Horizontal survey center line chaining is used to relocate the preliminary or construction stationing, so the final cross-sections may be taken at the exact location of the preliminary or construction cross-sections to secure accurate earthwork quantities.

B. Pavement center line surface measurements are made by chaining on the surface of the pavement along the center line of the pavement. Surface measurement is used to allow the preparation of straight line diagrams as graphic mileage records of the improvement and locate structures, intersecting roads, political sub-division lines, cross drains, and other physical characteristics needed for the straight line diagrams, and as a check on the inspector's record of payable quantities for items such as curbing, sidewalks, guard fence, pavement, and other items of the contract.

C. Surface measurement shall be tied in with horizontal chain stationing at the beginning and end of the bridge floor, of all bridges, roadway intersections, and changes in type of width of pavement, to allow a comparison of surface measurement with horizontal measurement at short intervals. The stationing applying to each method shall be plainly identified in the notes so there will be no confusion. Curves shall be chained on the center line arc.

13–4 CROSS-SECTIONS. Final cross-sections must be taken at all stations and plusses and at the same angles to the center line as the original cross-sections had been taken on the preliminary or construction survey in order to insure perfect coordination of sections and secure accurate earthwork quantities. Additional final sections shall be taken at the beginning and end of all cuts and fills. The district office will interpolate the preliminary sections at these stations. The final cross-sections shall be extended on each side of the center line, so that the last two readings on each side will definitely be original ground elevations and these readings shall be marked "O. G.". In like manner the bottom of fill shall be marked "B. F." and the top of cut "T. C.", while the edge of pavement shall be marked "E. P." in accordance with the instructions regarding symbols and abbreviations to be used in Chapter Fifteen of this Manual.

A. Ground elevations as noted on the preliminary or construction survey shall be checked against the elevations obtained on the final survey and any discrepancies must be noted and explained. If a section falls at the inlet or outlet of a pipe, that section shall be taken as if there were no break in the slope line. This will permit the averaging of that section in each direction with accuracy.

B. Cross-sections on channel changes are usually taken shortly after completion, however, additional material may have been washed in necessitating additional cleaning. New cross-sections showing the material washed in and final cross-sections, after its removal, must be taken for accurate determination of quantities. When not shown on the drawings a channel layout sketch shall be prepared showing the location of the established traverse line with respect to the roadway. This sketch shall be sufficiently accurate and complete so that when plotted, the channel and roadway cross-sections can be tied in to eliminate overlapping of sections.

C. Final cross-sections of borrow pits shall be taken as outlined in Chapter Twelve of this Manual.

D. In any grading section, where no "Borrow" has been used, and fill areas completed are beyond the theoretical cross-section limits for width of shoulders and slopes, indicating a waste grading section in which measurements of embankments would not be involved in determination of the pay quantity for excavation, cross-section elevations of the fill areas will not be required beyond the outer edges of the shoulders, provided the fill slopes have been constructed properly to at least the slope as planned. These outer limits of such final cross-sections should be marked "S. L. W." (Shoulder limit in Waste Areas), and embankment quantities need not be computed.

E. All final cross-sections, profiles, and other computations shall be made and checked in the field by the corps and noted by whom computed and by whom checked, this work being performed each night and shall be completed when the survey is finished and the books forwarded to the district office. The field work should be a completed operation, and the chief-of-party will be held responsible for this work, and also for forwarding the notebooks to the district office without delay.

13–5 BENCH MARKS. The bench marks appearing on the construction drawings shall be checked and elevations recorded for all new bench marks established. Department standard bench marks placed during construction on bridges and other permanent structures shall be described so as to be easily located in the future and the elevation noted to the nearest hundredth (0.01) of a foot, and plainly identified in the notes as new bench marks established during construction. Any old bench marks damaged or destroyed shall be so indicated in the notes. The final drawings shall void such damage or destroyed bench marks, and shall show the data for the new bench marks established during the construction.

13–6 MEASUREMENTS. Measurements for the determination of final pay quantities shall have been taken by the inspectors during construction or by the survey party at the time of the final survey. Usually the inspector-in-charge of the project has recorded measurements for all items of the contract except roadway excavation, borrow, large amounts of waste material that need cross-sectioning, parallel ditches within the cross-section area, bridge cross-sections, and approaches on which preliminary or construction cross-sections were taken.

A. The chief-of-party should determine in advance the work needed to be done to complete the final estimates and drawings.

B. Final cross-sections, profiles, and measurements must be taken on all side approaches to the highway where grading has been performed unless the quantity of cut and fill are slight and previously measured and computed by the inspectors. Layout sketches and measurements are necessary to enable the district office to accurately determine the amount of cut or fill.

C. Cross drains shall be measured according to Section 6.25.4 of the Specifications, the stational plus for the inlet, outlet, and center line crossing noted and the type and size of pipe and type of endwalls recorded. Elevations of the flow line at the inlet and outlet ends shall be recorded.

D. Surface measurements shall be used in chaining the pavement and a recheck made and the quantity of the different types of surface computed. Widening on curves shall be measured on ten (10) foot chords and aprons and paved intersections accurately measured and computed. Clear and accurate sketches shall be shown for all additional paving beyond the normal width of the standard section and for the transition from one width to another.

E. Curbing, guard fence, underdrain, and similar items shall be measured and located by stational plusses at beginning and end when the pavement is surface chained, in accordance with the basis of payment for each item as given in the Specifications. The identification of the contract item shall be recorded, such as type, size, and similar designations.

F. Tile outlet endwalls, standard pipe culvert endwalls, inlets, and similar physical items, shall be located by stational plusses when surface chaining.

G. Special emphasis is placed on securing accurate quantities for all material wasted throughout the project, particularly at channels and ditches. When not obtainable by cross-sections the amount of the waste material shall be measured by average dimensions and recorded with a sketch in the notebook showing its location with relation to the highway.

13–7 **FINAL BRIDGE AND CULVERT SURVEYS.** The chief-of-party shall confer with the inspector-in-charge and determine if all final computations and sketches have been prepared, relating to the bridge, culvert, and channel change. If additional information is required the chief-of-party shall obtain it when making the final survey.

CHAPTER FOURTEEN

CONDEMNATION OF RIGHT OF WAY SURVEYS

GENERAL

14–1 Every right of way survey and drawing must be very accurate and complete, including the correct location and designation of all property ownership. Such drawings are the basis for determining all property damages which may be involved, and they are the legal record indicating the location, extent, and character of any condemnation of right of way.

14–2 A right of way survey or drawing should be premised on condemning a required width of right of way not less than the width of the existing right of way. Since the passage of Act Number 548, effective November 19, 1959, there is no fixed maximum of width for a public highway. The width to be acquired is discretionary with the Secretary of Highways. However, the minimum width of a public highway in this Commonwealth is 33 feet, except where a lesser width is on record.

14–3 Since there is no longer a fixed minimum width of right of way, it will be general practice to extend the width of the right of way to include cuts and fills which previously had been condemned as slope areas. Therefore, it will be necessary in many cases to provide offsets to include such areas. These offsets should be perpendicular to the center line and in increments of not less than 10 feet. These "breaks" in a line should be at intervals of no less than 200 feet and the right of way line should be parallel to the center line of the highway.

14–4 The minimum required right of way in rural areas for Interstate Class 1 and Ultimate Class 1 highways in flat and rolling terrain shall be 200 feet plus median; and in mountainous terrain 300 feet plus median. In urban areas the required right of way may be reduced to 120 feet plus median where found economically feasible. Minimum right of way for Class 2 and Class 3 shall be 80 feet; for Class 4 and Class 5—60 feet.

14–5 A survey for condemnation of right of way is ordinarily coincidental with the construction survey, as is outlined elsewhere in this Manual. Before such survey is started, the district engineer should advise the chief-of-surveys of the proposed required width of right of way, and that width should be decided only after a very careful consideration of present and future requirements. The location engineer should select a location for the highway which will minimize the combined construction and property damage costs.

ULTIMATE RIGHT OF WAY SURVEYS

14–6 The purpose of such a survey is to prevent improvements from being made in areas adjacent to a State highway route or along the logical future location of said route. To be effective, a drawing which provides for the establishment of ultimate right of way lines must be recorded in the county seat of the county wherein the route is located. The recorded drawing does not actually condemn

right of way, and thereby make any political subdivision liable for property damages, but it does establish lines which restrict future property improvements. In other words, if a property owner, subsequent to the recordation of such a drawing, should erect a structure or make any improvement within the ultimate right of way lines shown on the recorded drawing, he does so at his own risk and cannot recover damages for same if later said structure or improvement is included within an area condemned by this Department.

14–7 Before a district engineer submits his recommended width for an ultimate right of way, supported by facts and information which will justify that width, he should make careful studies to determine the probable future amount of traffic expected to use the general location, as well as the general character of that traffic. Under no circumstances should the survey made in the field be started until Central Office approval has been secured for a definite ultimate width of right of way. Nor should the field survey be started until after careful consideration has been given, and definite decisions reached, relative to the matters of maximum curvature and gradients, as well as minimum horizontal and vertical sight distance. The ultimate width and future alignment of a route must be logically determined. Thereafter the survey party should proceed to establish the center line of the ultimate location. "Ultimate center line", is the center line of the highway as it will ultimately be constructed, a practical location, yet not necessarily a reproduction of the construction center line as established previously. In many cases the present center line represents the ultimate location. However, no special effort should be made to have the ultimate survey on the present road when it is apparent that future construction will require a different location.

14–8 The same, or even a greater degree of accuracy holds true for right of way surveys as for any other type of highway survey and should be so regarded at all times.

14–9 After an ultimate right of way center line has been established, complete topography should be taken, including everything within one hundred feet of the center line, on both sides. Any object outside this area which might have an effect on property damages should also be located. Care should also be used in taking this topography to insure that every building or improvement is carefully and accurately located. Accurate dimensions of each building, its number of stories, and types of construction should be obtained. Property owners' names, their addresses, and property lines should be obtained by local inquiry and verified, if necessary, by other means. Streams, intersecting roads, and railroads should be located accurately in the field and on the drawings.

14–10 All P.C.'s P.I.'s P.T.'s P.O.T.'s and P.O.S.T.'s should be carefully referenced to at least three permanent objects wherever possible. If necessary, established referenced points at other locations where suitable reference objects are available. It is all important that the established center line be capable of exact reproduction for years to come.

14–11 True bearings must be shown on every course on the drawings, thus requiring the establishment of True North by observation at given intervals.

14–12 Assuming that the Central Office has authorized the preparation of an ultimate right of way drawing, all that is expected of the district office is to

make a complete and accurate survey and drawings, observing the following matters:

1. Only straight line diagram stationing should be used.
2. Use "Transition Curves for Highways" from handbook published by the United States Department of Agriculture, with horizontal stationing.
3. True North to serve as the basis of all bearings.
4. Use of stationing inequality to be avoided, if possible.
5. Sufficient and well selected references made to the ultimate center line for later re-establishment purposes.
6. The drawings must show complete, accurate, and detailed topography within the ultimate right of way lines, especially so, as concerns buildings and other improvements.
7. No profile or cross-section information is to be shown on the drawings.

SURVEYS FOR OBTAINING UNOBSTRUCTED VIEW

14–13 So-called safe-sight drawings are prepared and recorded whenever it becomes necessary to eliminate or preclude any obstruction of sight at highway intersections, grade crossings, or the inside of curves, and when such obstruction is located outside the area which may legally be condemned for required right of way purposes. An Act approved and effective on June 9, 1939, permits the condemnation of additional right of way at road intersections and grade separation structures, hence there should now be but infrequent need for the recording of safe sight drawings in the manner as was required prior to the passage of the 1939 Act.

14–14 A survey and drawings which are intended for the purpose of obtaining an unobstructed view are made in the same manner as for an ordinary condemnation of right of way of property.

14–15 Safe sight areas, in most instances, require a survey similar to a property survey. The base line for such a survey should be the highway center line and all bearings should be based on True North. Sufficient references should be made, and shown on the drawings, to enable the re-establishment on the ground of all right of way lines. All property lines and property ownership should be shown. on the drawings. Likewise all topography and improvements should be shown. The parcel, of course, is made up of that area between the highway right of way lines and the line, or lines, necessary to provide the proper safe sight distances.

ABANDONED CANALS AND RAILROAD OR RAILWAY RIGHTS OF WAY

14–16 Under certain conditions the Department has the right to acquire or condemn all or part of an abandoned canal, or abandoned railroad or railway right of way. The application of this right is resorted to very infrequently, and when the need arises the district office will be furnished with specific and detailed instructions.

14–17 Surveys for acquiring abandoned canals, or rights of way of abandoned railroads or railways shall be made in the same manner as any other right of way survey, in that, the survey corps should establish the logical center line for the

purpose of constructing a highway on the location of the abandoned canal, railroad or railway; with the exception of the fact that it is necessary to also establish the right of way lines on either side. In this case the right of way lines are represented by the boundry lines of the abandoned canal, or railroad or railway right of way.

14–18 The deed applying to the abandoned canal, railroad or railway should be obtained and carefully resurveyed by our survey corps and property referenced to our highway survey center line by center line offsets at every property corner, and oftener if considered essential.

PROPOSED FUTURE LOCATION FOR HIGHWAY

14–19 A "proposed future location" is the restriction of an area which is to be used in the future for a proposed highway. The method of preparing and recording the drawing is the same as for the establishment of an "Ultimate Right of Way." The difference in characteristic between the two types is that ultimate right of way is predicated on the future relocation of a present route while future location plans are predicated on the future establishment of a new route.

14–20 Future location surveys are made in the same manner as is described for ultimate right of way.

SURVEY WITHIN THE LIMITS OF A PUBLIC UTILITY COMMISSION ORDER

14–21 Property lines must be accurately determined and shown on the drawings. The title must be searched and uncertain property lines re-established. All property lines must be established and referenced in relation to the survey center line.

14–22 The property owner of record at the time the property is appropriated, and post office address, must be secured for each parcel. The name of the grantor, date of the deed, date of transfer, deed book number, and number of the page on which the deed is recorded, must also be obtained.

14–23 Separate property surveys are no longer necessary, and should not be made unless specifically instructed to do so.

CHAPTER FIFTEEN

CARE AND PREPARATION OF NOTEBOOKS SYMBOLS—CONVENTIONS

15–1 Care of Notebooks. Survey notes are original records and the greatest care shall be exercised to guard against loss of, and prevent damage to, any notebooks or part thereof. Each chief-of-party or other person using a notebook shall be charged with its safe custody and will be responsible for returning it in good condition to the district office or to his immediate superior. Valuable notebooks, costly to replace have been lost in the past and to avoid this, dated receipts shall be given for the passing of notebooks from one person to another. Pages shall not be removed from a notebook for any cause whatsoever. If the notes are obsolete, they shall be so marked. Keep the notebooks clean and do not crowd the notes.

15–2 Preparation of Notebooks. The resulting drawings and the efficiency with which they are prepared depends to a great extent upon the adequacy and clearness of the survey notes. Incomplete and illegible notes are usually due to carelessness. The person plotting the survey notes will not have the advantage of being on the ground and the survey notes should be clear and complete, so as to present a mental picture of the location or condition to the draftsman so he may be able to visualize the field condition. If you feel further details will present the picture in a clearer manner, show a sketch in the back of the book with a reference to it in your notes.

The notebooks (Form 428) on all surveys shall show on the front page the date of starting and completion of the survey, the route number, section number, application number, township, borough, city, county, district engineer's name, and address of the district office, Department district number and names and titles of the survey party. Each day's work should show the names of the survey party, temperature and weather. The pages of the notebooks are numbered and a complete table of contents should be shown under "Index," and the type of survey and notes in each book designated.

All survey notes shall follow the standards as prescribed and use the symbols as shown in this Manual insofar as they apply. All notes shall be lettered.

Computations for curves, levels, etc., shall be made and kept on the last few pages of the notebook to which they apply. Do not perform these basic computations on scratch paper to be thrown away. Notes shall be kept with a sharp, hard pencil.

Before turning notebooks into the district office, all computations shall have been completed and checked by competent members of the survey party. Upon completion of a survey all notebooks shall be assembled in order and forwarded to the district office. If the district office requires the notebooks as the survey progresses, sufficient information should be copied in the next notebook to proceed with the work before releasing the notebooks. Copied notes shall be marked to indicate that fact, so there will be no mistake as to which are original notes and which are copies.

Standard methods of keeping notes are shown at the end of this chapter.

THE FOLLOWING STANDARD SYMBOLS, ABBREVIATIONS AND DESIGNATIONS MAY BE USED

Abutment	Abut.
Application	Appl.
Approach	Appr.
Approximate	Approx.
Asphalt Coated Corrugated Metal	A.C.C.M.
Bituminous Surface Course	Bit. Surf. Crse.
Borough	Boro.
Bottom Cut	B. C.
Bottom Fill	B. F.
Bottom Wall	B. W.
Brick	Br.
Building	Bldg.
Cast Iron Pipe	C. I. P.
Cement	C.
Center to Center	C. to C.
Concrete Pipe	C. P.
Construction	Constr.
Corrugated Metal Pipe	C. M. P.
County	Co.
Creek	Ck.
Cubic Yard	C. Y. or cu. yd.
Curb, Bottom of	B. C.
Curb, Face of	F. C.
Curb, Top of	T. C.
Diameter	dia.
Dimension	Dim.
Drive	Dr.
Dwelling	Dwg.
Edge, of Concrete	E. C.
Edge, of Road	E. R.
Electric Railway	Rwy.
Elevation	Elev.
Embankment	Emb.
Endwalls	Edw.
Excavation	Exc.
Expansion	Exp.
Feet	Ft. or '
Fence	F.
Fence Post	F. P.
Floor	Fl.
Flow Line	F. L.
Foundation	F'd'n.
Frame Dwelling	Fr. Dwg.
Garage	Gar.
Ground (Original at intersection of new slopes and beyond)	O. G.
Guard Fence	G. F.
Guard Posts	G. P.
Highway	Hwy.
House	Ho.
Inches	in. or "
Information	Info.
Joint	Jt.
Left	Lt.
Lineal	Lin.
Longitudinal	Long.
Manhole	M'hole
Masonry	Mas.
Maximum	Max.
Miles	Mi.
Minimum	Min.
Monument	Mon.
Pavement	Pavt.
Percent	%
Plain	Pl.
Property Line	P. L.
Railroad	R. R.
Reference	Ref.
Reinforced or Reinforcement	Reinf.
Reinforced Cement Concrete	R. C. C.
Reinforced Concrete Pipe	R. C. P.
Revision	Rev.
Right	Rt.
Right-of-way	R/W
Roadway	Rdwy.
Route	Rte.
Section	Sect.
Square Yards	sq. yds.
Standard	Std.
Steel	St.
Story	Sty.
Stream	Str.
Subgrade	subg.
Substructure	Substr.
Superstructure	Superstr.
Superelevation or superelevated	Supvl.
Surface	Surf.
Temperature	Temp.
Terra Cotta Pipe	T. C. P.
Top Cut	T. C.
Top Fill	T. F.
Top Rail	T. R.
Top Wall	T. W.
Topography	Topo.
Township	Twp.
Transverse	Transv.
Vertical	Vert.
Vitrified Clay Pipe	V. C. P.
Underdrain	Udrain
Walk	Wk.
Wearing Surface	Wear. Surf.
Widened Curve	W. C.
Wingwall	W. W.
Yards	yds.

CURVE DATA

PI	—Point of Intersection	T. S.	—Tangent Spiral
D	—Degree of Curve	H. I.	—Height of Instrument
	—Delta-Ext. Angle	B. S.	—Back Sight
T	—Tangent	F. S.	—Front Sight
R	—Radius	T. P.	—Turning Point
L	—Length of Curve	B. M.	—Bench Mark
PC	—Point of Curve	L	—Angle
PT	—Point of Tangent	C-L	—Center Line
POT	—Point on Tangent	XSec.	—Cross-Section
POC	—Point on Curve	Defl.	—Deflection
POST	—Point on Subtangent	Mag.	—Magnetic
PCC	—Point of Compound Curve	Tp. S.	—Top of Stake
C. S.	—Curve Spiral	B. S.	—Bottom of Stake
S. C.	—Spiral Curve	Sta.	—Station
S. T.	—Spiral Tangent		

These symbols are important, and should not be omitted.

Any other symbols used to designate ownership of pole lines, railroads, etc., such as P. P. & L. for Pennsylvania Power and Light Co., or P. R. R. for Pennsylvania Railroad Co., should be noted in the beginning of the books where such symbols are used.

Figure 15–1

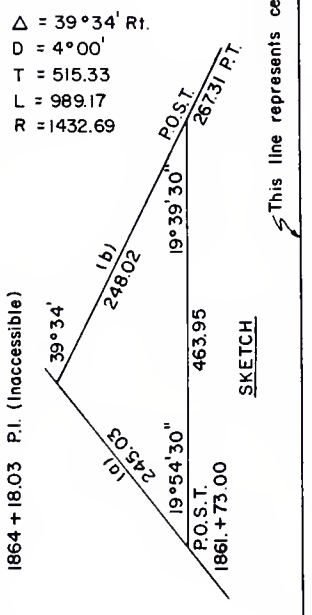
Sta.	Angle	Double	Def.	Bearing Mag.	Bearing True
			TRANSIT NOTES		
P.T.					
1868 + 91.87			19°47'	S 77°30'E	S 86°27'E
+50			18°57'		
1868			17°57'		
+50			16°57'		
1867			15°57'		
+50			14°57'		
P.O.S.T.					
267.31' Back of P.T.	199°39'30"	39°19'	19°39'30"		
1866			13°57'		
+50			12°57'		
1865			11°57'		
+50			10°57'		
P.I. (Inaccessible)					
1864 + 18.03	219°34'	79°08'	39°34'	S 77°30'E	S 86°27'E
	(Computed)				
1864			9°57'		
+50			8°57'		
1863			7°57'		
+50			6°57'		
1862			5°57'		
P.O.S.T.					
1861 + 73.00	199°54'30"	39°49'	19°54'30"		
+50			4°57'		
1861			3°57'		
+50			2°57'		
1860			1°57'		
+50			0°57'		
P.C.					
1859 + 02.70			0°00'	N 62°56'E	N 53°59'E

$a = \frac{463.95 \times \sin 19°39'30"}{\sin 39°34'} = 245.03$

$b = \frac{463.95 \times \sin 19°54'30"}{\sin 39°34'} = 248.02$

COMPUTATIONS

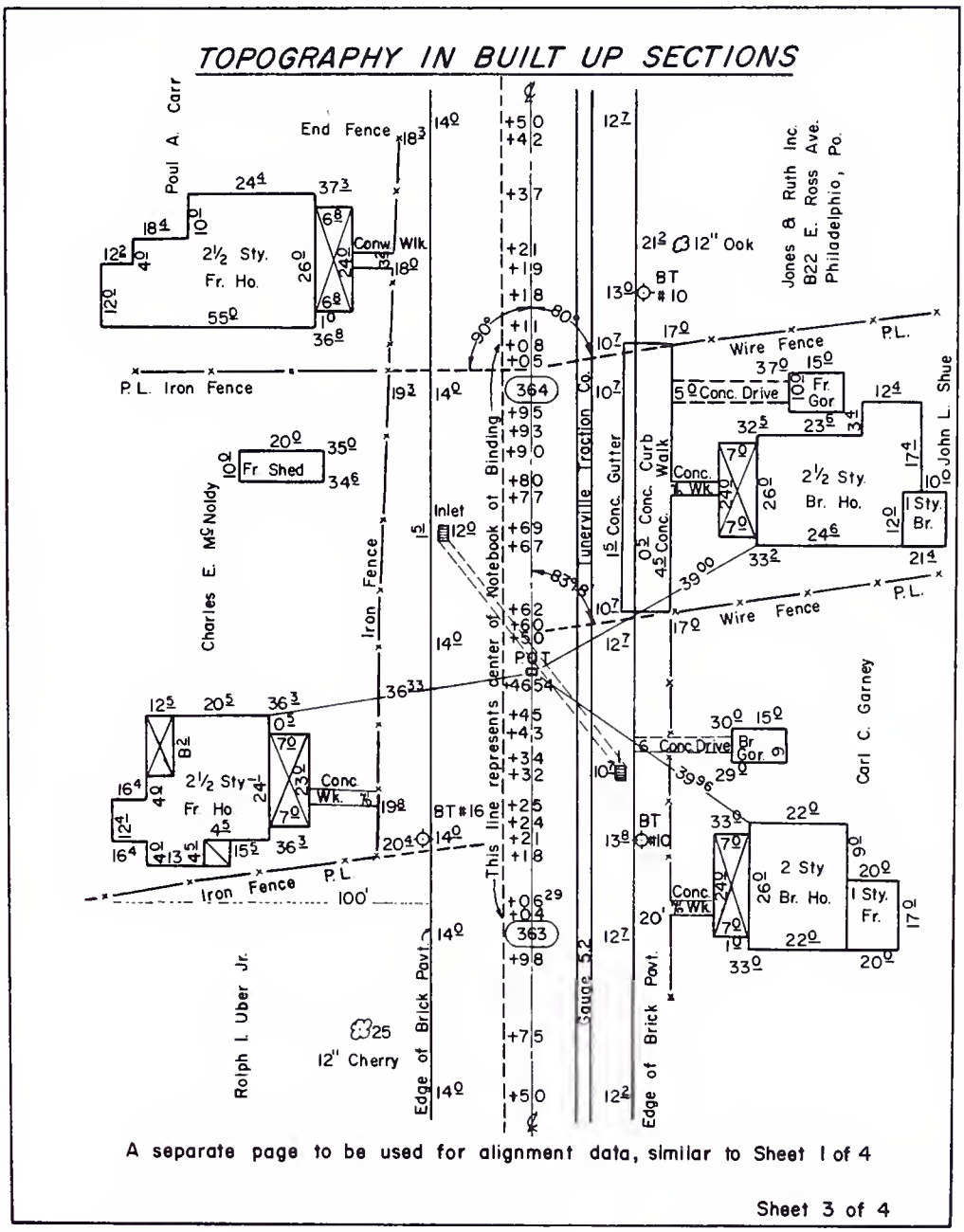
Δ = 39°34' Rt.
D = 4°00'
T = 515.33
L = 989.17
R = 1432.69



This line represents center of notebook at binding

Sheet 1 of 4

Figure 15–2



A separate page to be used for alignment data, similar to Sheet 1 of 4

Sheet 3 of 4

Figure 15–3

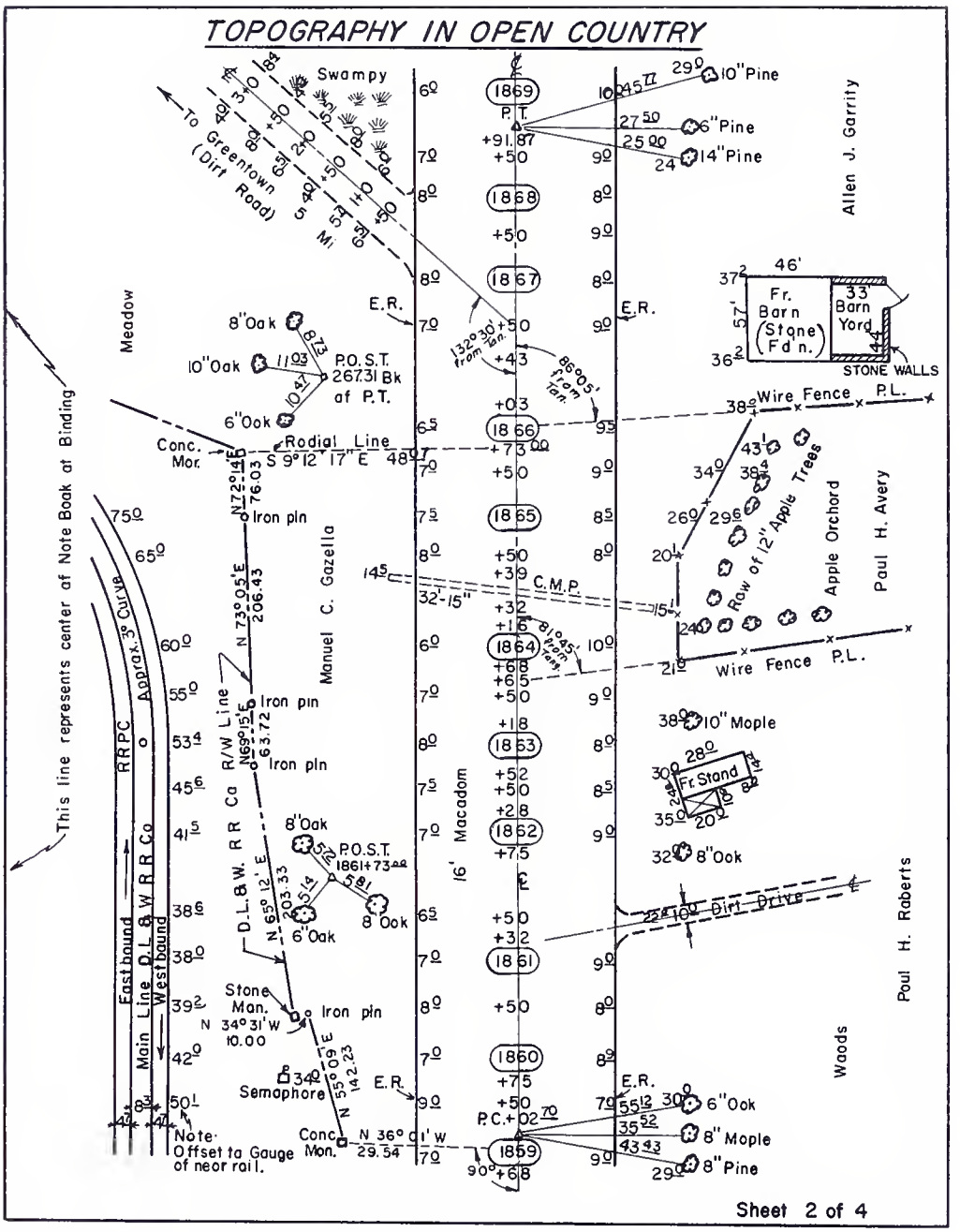

TOPOGRAPHY IN OPEN COUNTRY
Swampy
To Greentown (Dirt Road)
Meadow
E.R.
8"Oak
10"Oak
6"Ook
P.O.S.T. 267.31 Bk of P.T.
Conc. Mor.
Radial Line
S 9° 12' 17" E 48.07
N 72° 14' E 76.03
Iron pin
N 73° 05' E 206.43
Manuel C. Gazella
N 69° 15' E 63.72
R/W Line
D.L.&W. R.R. Co
N 63° 12' E 203.33
8"Oak
6"Oak
8 Ook
P.O.S.T. 1861+73.00
Stone Mon.
N 34° 31' W 10.00
Semaphore
N 55° 09' E 142.23
Conc. Mon.
N 36° 01' W 29.54
Note· Offset to Gauge of near rail.
This line represents center of Note Book at Binding
RRPC
Approx. 3° Curve
Main Line D.L.&W.R.R.Co
Eastbound
Westbound
16' Macadom
P.T.
+91.87
1320° 30' from Sta.
+43
86° 05' from Sta.
+03
+73.00
C.M.P.
+32
+16
8"Oak
+68
+65
+18
+52
+28
+75
+02.70
P.C.
1869
1868
1867
1866
1865
1864
1863
1862
1861
1860
1859
10"Pine
6"Pine
14"Pine
Allen J. Garrity
Fr. Barn (Stone Fd'n.)
Barn Yard
STONE WALLS
Wire Fence P.L.
Apple Orchard
Row of 12" Apple Trees
Paul H. Avery
Wire Fence P.L.
10" Mople
Fr. Stand
8"Ook
Dirt Drive
Paul H. Roberts
Woods
6"Ook
8" Mople
8"Pine
Sheet 2 of 4

Figure 15–4

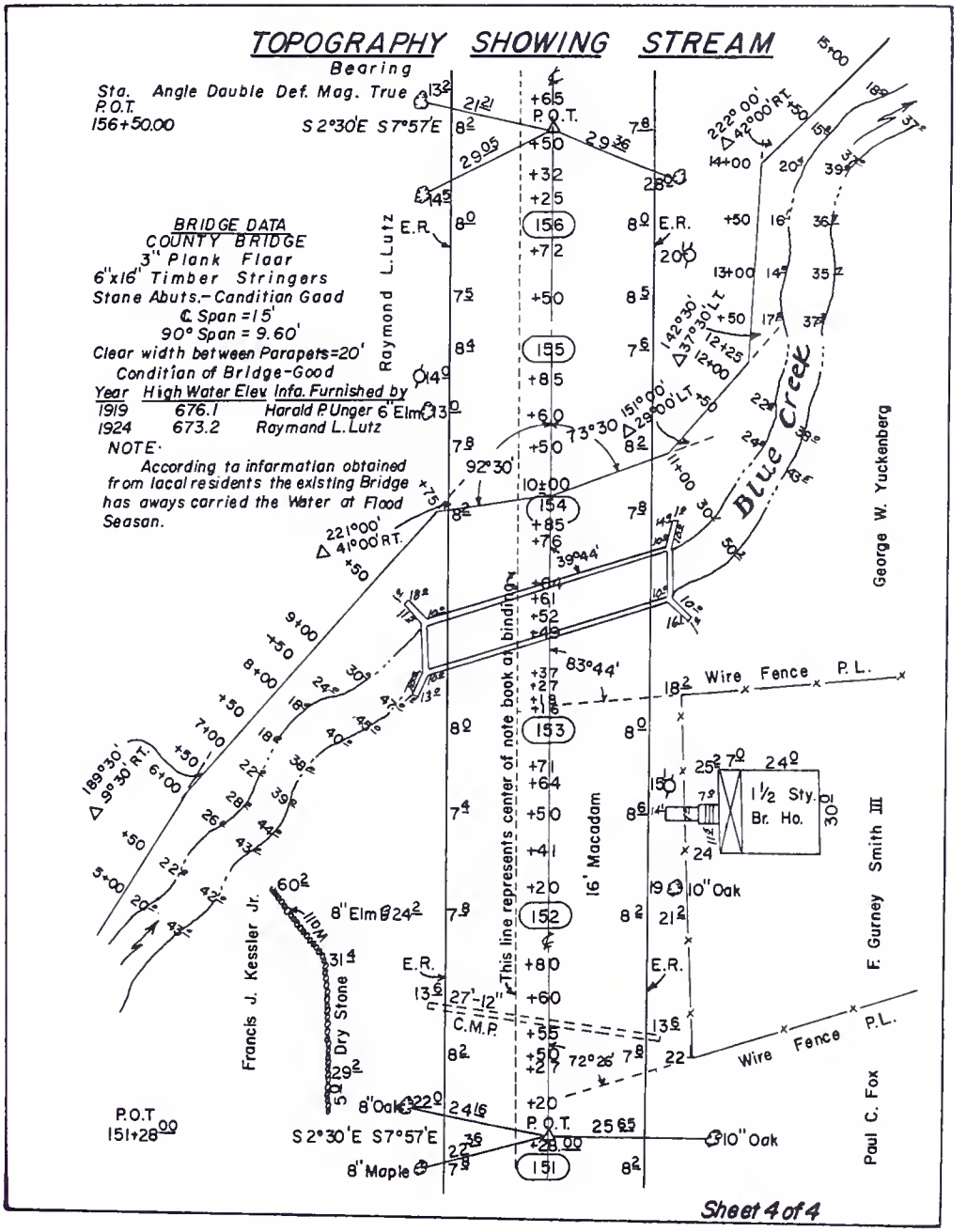

TOPOGRAPHY SHOWING STREAM
Bearing
Sta. Angle Double Def. Mag. True
P.O.T.
156+50.00
S 2°30'E S 7°57'E
BRIDGE DATA
COUNTY BRIDGE
3" Plank Floor
6"x16" Timber Stringers
Stone Abuts.- Condition Good
℄ Span = 15'
90° Span = 9.60'
Clear width between Parapets=20'
Condition of Bridge-Good
Year High Water Elev Info. Furnished by
1919 676.1 Harold P Unger
1924 673.2 Raymond L. Lutz
NOTE:
According to information obtained from local residents the existing Bridge has always carried the Water at Flood Season.
Raymond L. Lutz
E.R.
P.O.T.
156
155
154
153
152
151
Blue Creek
George W. Yuckenberg
F. Gurney Smith III
Paul C. Fox
Francis J. Kessler Jr.
16' Macadam
This line represents center of note book as binding
Wire Fence P.L.
1½ Sty. Br. Ho.
8" Elm
10" Oak
8" Oak
8" Maple
Dry Stone
C.M.P.
P.O.T.
151+28.00
S 2°30'E S 7°57'E
P.O.T. 25+65
10" Oak
Sheet 4 of 4

Figure 15–5

Sta.	+ B.S.	~ H.I	− F.S.	Elev.			Weather: Cold, Windy

PRELIMINARY CROSS – SECTIONS

B.M. ~10					141352	Spike in root of 12" Pine 50' Rt. of Sta. 1732+31							
	022	141374											
		HOUSE	T.S.	B.S.		E.R.		E.R.		F.			
1732		485	32.0	32.0	15.0	7.0	℄	8.0	15.0	25.0	42.0	50.0	60.0
		7.2	5.24	5.8	5.8	5.0	4.6	4.0	3.3	3.3	2.0	1.6	2.0
		06 5	08.50	07.9	07.9	08.7	14091	09.7	10.4	10.4	11.7	15.3	15.7
				T.S.	8 S.		℄		8.C.	T.C.	Walk		B. Porch Por. Fl.
+50			50.0	32.0	32.0	16.0		8.0	14.0	14.0	18.0	22.0	26.0 26.0
			8.7	6.51	7.0	6.0	4.8	3.3	3.6	3.0	2.8	2.8	2.9 00
			05.0	07 23	06.7	07.7	14089	10.4	10.1	10.7	10.9	10.9	10.8 13.7
T.P.				8.43		1405.31							
	2.10		1407 41										
									T.R.	T.R.			
1733			56.0	30.0	16.0	8.0	℄	17.5	17.6	22.3	22.4	28.8	28.8
			4.3	3.4	3.2	3.1	2.6	1.9	1.6	1.6	1.9	1.3	100
			03.1	04.0	04.2	04.3	14048	05.5	05.8	05.8	05.5	061	06.41

FINAL CROSS – SECTIONS

	0.G.	0.G.	Waste			E.C.	℄	E.C.		0.G.	0.G.		
+50	35.0	30.0	25.0	20.0	18.0	14.0	9.0		9.0	14.0	16.0	20.0	
	7.8	7.6	6.8	6.8	7.6	9.3	4.83	4.61	4.82	5.0	8.0	7.6	
	99.6	9.98	00.6	00.6	9.98	9.81	02.58	1402.80	0259	02.4	99.4	99.8	
+80		Zero	Section	for	borrow.								
	C.G.	0.G.	BORROW				℄	E.C.			0.G.	0.G.	
1734	36.0	32.0	30.0	28.0	20.0	14.0	9.0		9.0	14.0	18.0	30.0	45.0
	2.3	2.0	2.0	4.0	4.3	4.2	3.98	3.82	3.98	4.2	4.3	4.6	4.8
	05.1	05.4	05.4	03.4	03.1	03.2	03.43	1403.59	03.43	032	03.1	02.8	02.6
T.P.					5.94		1401.47						
	2.07		1403.54										
B.M. ~ 11					9.70		1393.84 (1393.83)	Spike in root of 6" Oak 41' Lt. of Sta. 1734.83					

Abbreviations

E.R. = Edge of Road
E.C. = Edge of Concrete
8.C. = Bottom of Curb
T.C. = Top of Curb

This line represents center of notebook at binding

Abbreviations

T.R. = Top of Rail
F. = Fence
8.S. = Bottom of Stake
T.S. = Top of Stake

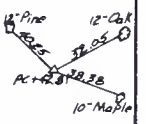
Sheet 1 Of 2

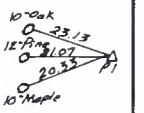
Figure 15–6

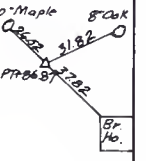
CONSTRUCTION STAKE-OUT

Sta.	Def. + B.S.	H.I.	F.S.	Top of stake rod	Elev.	Finished ℄ grade	Distance from top of stake to finished ℄ grade: Above	Distance from top of stake to finished ℄ grade: Below	Stake offset: Left	Stake offset: Right	Rod & elev. of ground at ℄	Alignment data
B.M.# 13		4.66 519.86			515.20							Spike in root of 20" Pine 50' Lt Sto. 1044
1045				5.21	514.65	512.31		2.34		26.98	4.2 515.7	
PC +42.81				4.19	515.67	513.59		2.08		23.78	4.2	
PC +42.81	0°00'			3.19	516.67	513.59		3.08	25.67		515.7	
+50	0°19'			2.26	517.60	513.81		3.79		24.98	4.8 515.1	
1046	2°34'			1.34	518.52	515.31		3.21		28.93	4.7 515.2	PI=1046+15.16 Δ=12°58' RT. D=9° T=72.35 L=144.06 R=632.27
+50	4°49'			1.01	518.85	516.81		2.04	26.71		5.2 514.7	
PT +86.87				9.08	510.78	517.92	7.14		36.50		6.0	
PT +86.87	6°29'			8.08	511.78	517.92	6.14			35.83	513.9	
TP		8.25 525.87	2.24		517.62							
1047				6.80	519.07	518.31		0.76	26.25		10.2 515.7	
+50				11.96	513.91	519.81	5.90		39.27		9.4 516.5	
B.M.# 14			6.56		519.31	(519.30)						Spike in root of 12" Oak 42' Rt Sto. 1048+19

This line represents center of note book at binding



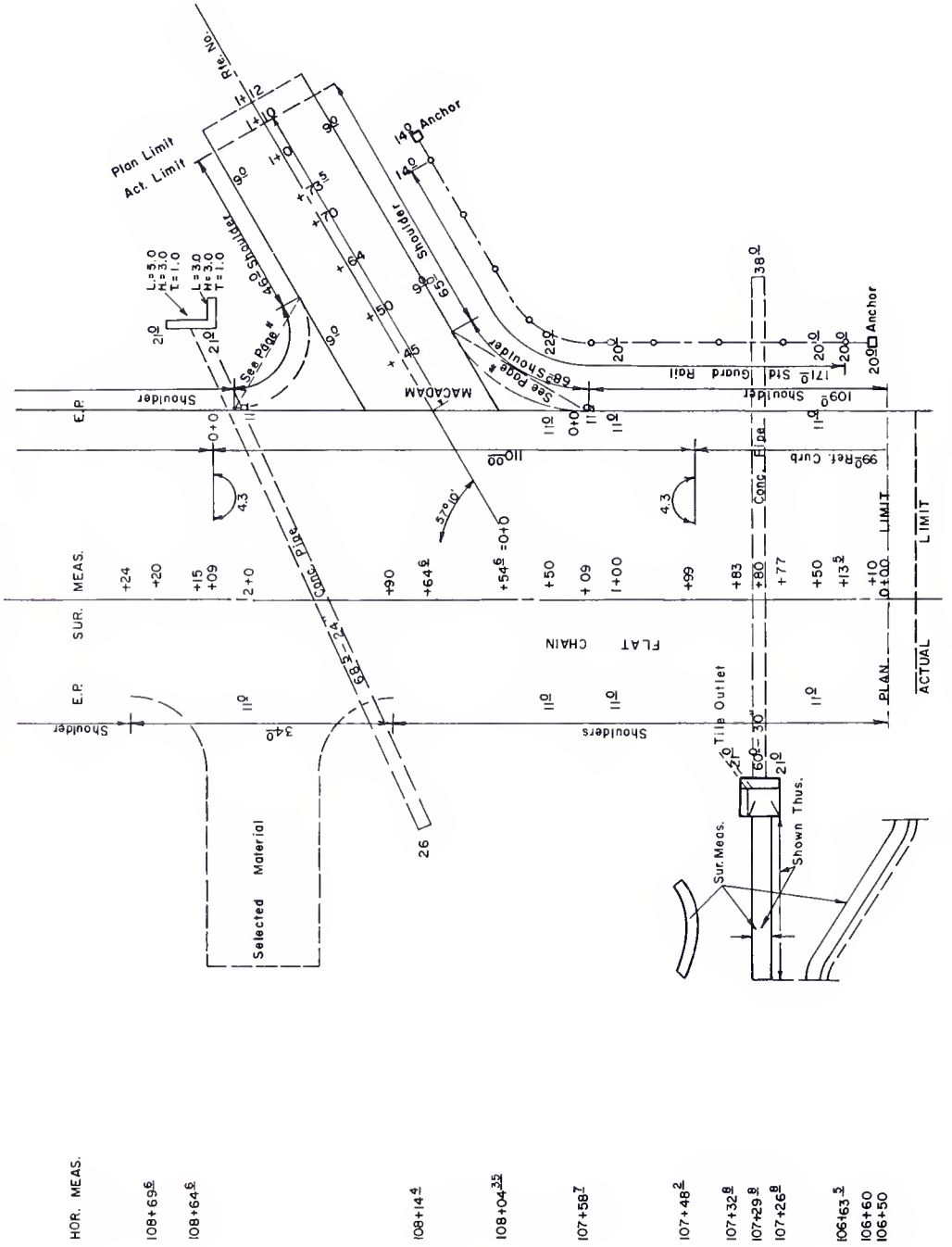




Sheet 2 of 2

Figure 15–7

FLAT CHAINING



HOR. MEAS.

108+69.6
108+64.6
108+14.4
108+04.35
107+58.7
107+48.2
107+32.8
107+29.8
107+26.8
106+63.3
106+60
106+50

Figure 15–8

FLAT CHAINING

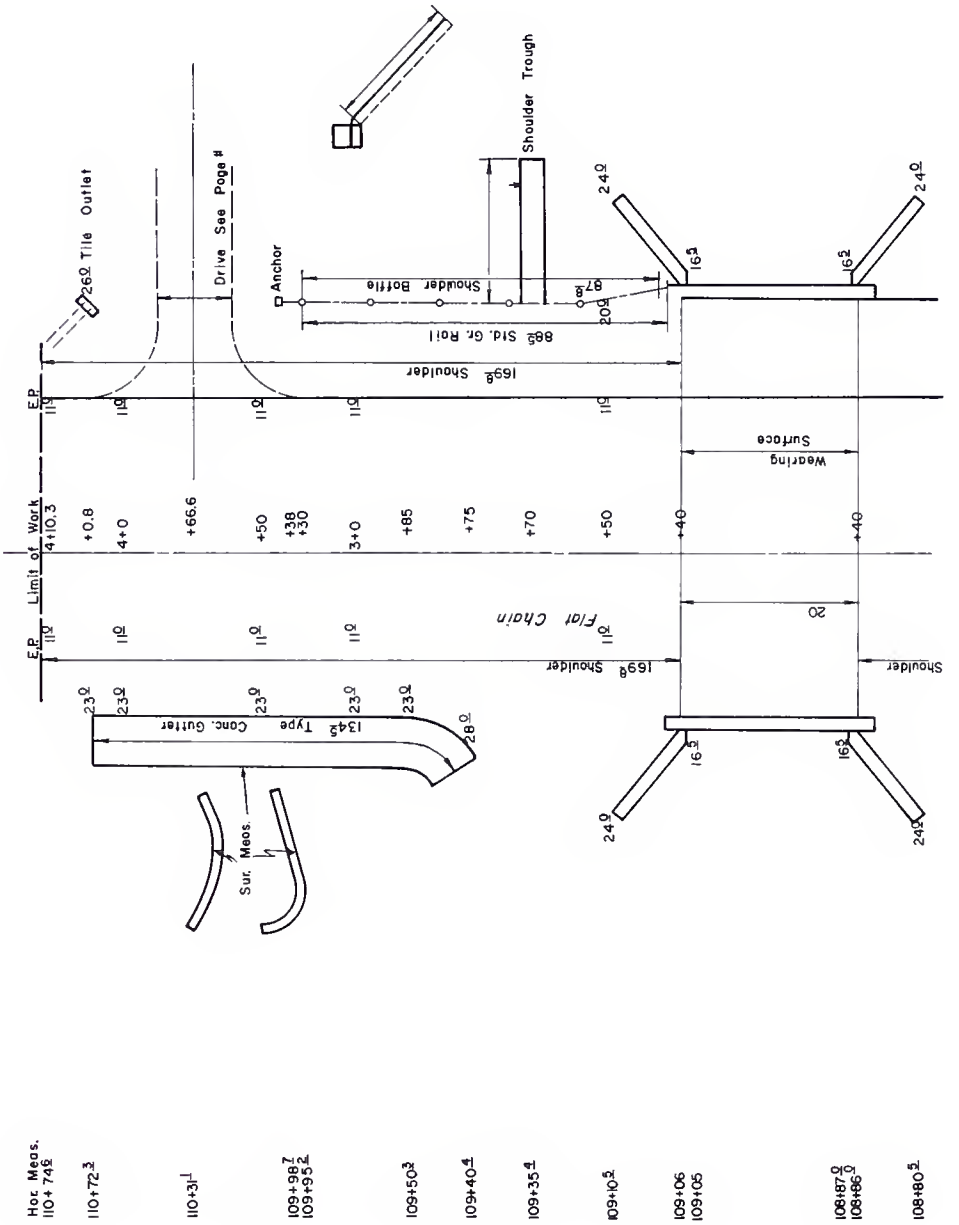
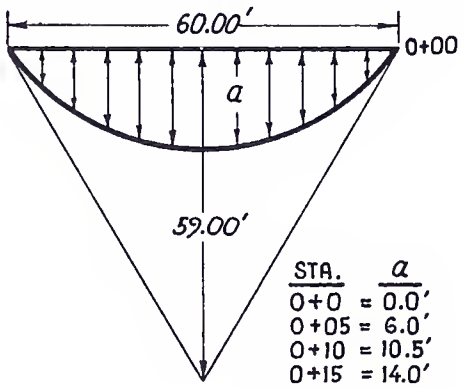


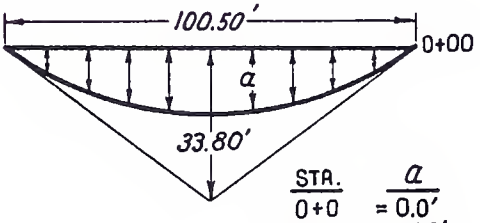
Figure 15–9

METHOD OF MEASURING PAY QUANTITIES FOR INTERSECTION RADIUS, DRIVEWAYS, AND WIDENED CURVES

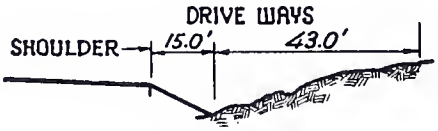
•RADIUS AT INTERSECTIONS•

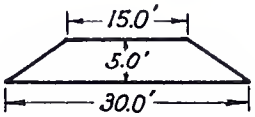


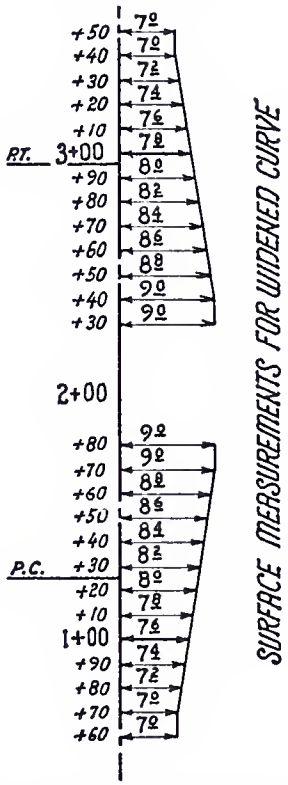
STA.	a
0+0	= 0.0'
0+05	= 6.0'
0+10	= 10.5'
0+15	= 14.0'
0+20	= 15.5'
0+25	= 17.0'
0+30	= 17.5'
0+35	= 17.0'
0+40	= 15.5'
0+45	= 14.0'
0+50	= 10.5'
0+55	= 6.0'
0+60	= 0.0'



STA.	a
0+0	= 0.0'
0+10	= 5.50'
0+20	= 10.00'
0+30	= 13.00'
0+40	= 14.80'
0+50	= 15.20'
0+60	= 14.70'
0+70	= 13.10'
0+80	= 9.90'
0+90	= 5.60'
1+00	= 0.0'







NOTE: CHECK ITEMS ON REQUIRED LIST FOR UNIT OF PAVEMENT (LIN. FOOT, SQUARE YARD OR CUBIC YARD)

Table 15–1

TABLES OF CURVES FROM 27° TO 55°
ACTUAL ARC METHOD

Degree Of Curve	Radius Of Curve	Deflection For 1 Foot ARC	Deflection For 25 Foot ARC	Deflection For 50 Foot ARC	Chord For 25 Foot ARC	Chord For 50 Foot ARC	Chord For 100 Foot ARC
27	212.21	08.1'	3°22.5'	6°45.0'	24.99	49.88	99.08
28	204.63	08.4	3°30.0	7°00.0	24.98	49.88	99.01
29	197.57	08.7	3°37.5	7°15.0	24.98	49.87	98.94
30	190.99	09.0	3°45.0	7°30.0	24.98	49.86	98.86
				10 Ft. Arc		10 Ft. Arc	
31	184.82	09.3	3°52.5	1°33.0	24.98	10.00	98.79
32	179.05	09.6	4°00.0	1°36.0	24.98	10.00	98.71
33	173.62	09.9	4°07.5	1°39.0	24.98	10.00	98.62
34	168.52	10.2	4°15.0	1°42.0	24.98	10.00	98.54
35	163.70	10.5	4°22.5	1°45.0	24.98	10.00	98.45
36	159.16	10.8	4°30.0	1°48.0	24.97	10.00	98.36
37	154.85	11.1	4°37.5	1°51.0	24.97	10.00	98.27
38	150.78	11.4	4°45.0	1°54.0	24.97	10.00	98.18
39	146.91	11.7	4°52.5	1°57.0	24.97	10.00	98.08
40	143.24	12.0	5°00.0	2°00.0	24.97	10.00	97.98
41	139.74	12.3	5°07.5	2°03.0	24.97	10.00	97.88
42	136.42	12.6	5°15.0	2°06.0	24.97	10.00	97.78
43	133.25	12.9	5°22.5	2°09.0	24.96	10.00	97.67
44	130.22	13.2	5°30.0	2°12.0	24.96	10.00	97.56
45	127.32	13.5	5°37.5	2°15.0	24.96	10.00	97.45
46	124.56	13.8	5°45.0	2°18.0	24.96	10.00	97.34
47	121.91	14.1	5°52.5	2°21.0	24.96	10.00	97.22
48	119.38	14.4	6°00.0	2°24.0	24.95	10.00	97.10
49	116.93	14.7	6°07.5	2°27.0	24.95	10.00	96.98
50	114.59	15.0	6°15.0	2°30.0	24.95	10.00	96.86
51	112.34	15.3	6°22.5	2°33.0	24.95	10.00	96.73
52	110.18	15.6	6°30.0	2°36.0	24.95	10.00	96.60
53	108.11	15.9	6°37.5	2°39.0	24.94	10.00	96.47
54	106.10	16.2	6°45.0	2°42.0	24.94	10.00	96.34
55	104.17	16.5	6°52.5	2°45.0	24.94	10.00	96.21

CHAPTER SIXTEEN

EQUIPMENT AND SUPPLIES

16–1 Engineering equipment is expensive and extra care must be used by those handling and using precision instruments to secure satisfactory service and avoid excessive repairs and adjustments. Careless use and handling of engineering equipment will impair the accuracy of the work performed and will not be tolerated.

16–2 The person to whom the equipment is issued and whose signature appears on Form 633, "Perpetual Inventory Material Receipt," will be held responsible for each piece of equipment issued to him. He will be required to reimburse the Department for lost equipment, or for the cost of repairs to equipment damaged or destroyed by his carelessness or through an inexcusable or avoidable accident.

16–3 SURVEY PERSONNEL CARS...A personnel car is assigned to each corps, under the care and responsibility of the chief-of-party for the transportation of personnel and equipment. It must be used with care and discretion and kept in good running condition at all times. The car shall be driven at moderate speeds by careful and competent drivers and should not be overloaded. The car shall be provided with suitable shelter when not in use and arrangements shall be made to have it serviced regularly and proper repairs and adjustments made as the need for such arise. The chief-of-party must have it inspected periodically by a Department mechanic. In the case of necessary repairs that would delay the work of the corps, he shall get in touch with his immediate superior for instructions.

16–4 TRANSPORTING EQUIPMENT. Survey parties will ordinarily carry their full equipment in their personnel car, so as to have it available at all times in the line of duty. Extreme care must be used in packing equipment, especially precision instruments to avoid damage by jolting, scratching or rubbing. Instruments shall be placed in their cases and the cases protected by suitable material which will absorb the shock and vibration.

16–5 ADJUSTMENT OF CONVENTIONAL SURVEYING INSTRUMENTS. The following information is printed as a guide for qualified instrumentmen and party chiefs in accomplishing field adjustments of the dumpy level, wye level, and transit. Any adjustment of surveying instruments must be done by experienced personnel or under the direct supervision of qualified personnel. Extreme caution must be utilized in all tests and adjustments of surveying instruments to attain the highest degree of accuracy. Complications will arise if a **faulty** test shows need to adjust an instrument that stands already in good adjustment. Therefore, it is wise to test an instrument twice before attempting any adjustment.

16–6 The DUMPY LEVEL.

1. Parallax.

Parallax errors are caused by faulty focusing of an instrument. Evidence of parallax occurs when the observer moves his eye from side to side while sighting through the telescope and sees an apparent movement of the cross-wires over the object being observed. Each individual observer should point the telescope toward the sky or a similar bright background and focus the eyepiece to bring out a sharp cross-wire image. This focus may vary due to the difference of each individual's eyes. The observer then properly focuses on the object by use of the objective focus and thereby has eliminated the apparent parallax.

2. Telescope Level Tube Test and Adjustment.

Set the level up with assurance that the tripod is sturdily placed. Level the instrument over both sets of screws. With the level standing perfectly level over one set of screws, rotate the level tube and level vial 180° about its vertical axis. If the instrument stands level now, it needs no adjustment. If the bubble does not center, adjust one half the error by use of the capstan nuts at the end of the level tube. Re-level and repeat the same operation until satisfactory results are obtained.

3. Horizontal Alignment of Cross-hair.

Sight the horizontal cross-hair on a well defined point by use of the leveling screws. The instrument need not be level for this adjustment or test. Revolve the scope about its vertical axis while observing the horizontal cross-hair traverse the defined point. If the entire horizontal hair traverses on the point, the instrument needs no adjustment. If the hair departs from the point, then loosen two adjacent capstan screws and tap the cross-hair reticule lightly until the desired effect is obtained. When satisfactory results are obtained, tighten the capstan screws to maintain the corrected position.

4. Cross-hair Collimation or Two Peg Test.

This test will show if the line of sight through the horizontal cross-hair is parallel to the axis of the level tube or vial. This is called the Two Peg Test. Place two pegs preferably about 300 feet apart. Set up the level equidistant between the two pegs. Observe the difference in elevation by sighting a level rod on each peg. This difference will be the true difference in elevation because any error would compensate itself due to equal sights. Then move the level to either one of the two pegs. Set up the level so that by looking through the objective end of the instrument, the eyepiece will be about one inch from the rod. After leveling, read a rod on the near peg by placing a pencil point on the rod and observing backward through the telescope. Compute the desired rod intercept of the second rod from the previous rod reading and the known difference in elevation. Observe the far rod. If the desired rod intercept is observed, no adjustment is necessary. If the instrument is out of adjustment, bring the line of sight to the desired rod intercept by moving the cross-hair reticule vertically with the capstan screws. After first adjustment, the test should be repeated to insure results.

16–7 THE WYE LEVEL.

1. **Parallax.**

   Same as Dumpy Level.

2. **Telescope Level Tube Test and Adjustment.**

   This test will prove if the level vial lies in a parallel plane with the wyes. Remove the pins from the wye clips, raise the clips to free the scope from the wyes and level the instrument to near perfection. Lock the scope over two leveling screws with the tangent clamp screw and relevel if necessary. Now carefully lift scope from wyes and turn it through 180°. Replace the scope in its wyes with the ends in a reversed position from its normal position. If the bubble centers, no adjustment is necessary. If the bubble does not center, correct half the error by means of the vertical adjusting nuts at the end of the level vial.

3. **Line of Sight or Collimation of Cross-hairs.**

   This test will prove if the line of sight lies in a parallel plane with the level vial. Remove pins and raise wye clips as in paragraph 2. Now sight the telescope on a well defined point. Carefully revolve the telescope in its wyes about its own axis and see if the same point is observed thru the present inverted telescope. If the line of sight remains the same, no adjustment is necessary. If in error, adjust half the error by means of adjusting reticule capstan screws.

4. **Cross-hair Collimation or Two Peg Test.**

   This adjustment is the same as on the Dumpy Level.

16–8 TRANSIT.

1. **Parallax.**

   Same as Dumpy Level.

2. **Cross-hair Alignment.**

   Set up the transit and level the plate levels. Sight the vertical hair on a well defined point and clamp both upper and lower tangent clamps. Move the telescope in a vertical direction and observe the vertical cross-hair as it passes along the sighted point. If the hair traverses on the point, the line of sight is in a plane perpendicular to the horizontal axis of the transit and no adjustment is necessary. Should the vertical hair move off the point, loosen two adjacent capstan screws on the cross-hair reticule and turn the ring slightly until the desired effect is achieved. Now tighten the capstan screws to desired snugness.

3. **Plate Levels.**

   In order that each plate level bubble remains centered when turning a transit to different positions, the axis of each level must be perpendicular to the vertical axis of the transit. Level the transit with each level vial parallel to a pair of opposite leveling screws. Now rotate the telescope through 180°. If the vials are still level, no adjustment is necessary. If either of the bubbles do not remain centered, adjust half the error by means of the screws on the plate levels. Re-level and test again to insure results.

4. **Collimation of Vertical Cross-hair.**

A common operation of the conventional transit is known as double-centering. This is a method of correcting an error caused by the line of sight not being perpendicular to the horizontal axis of the transit. Make a standard set-up with the transit. With the telescope direct, sight a well defined distant point. Now plunge or "flop" the scope and mark the line of sight about the same distance away as the original sight. Unclamp the one tangent screw, rotate the scope around 180° on its vertical axis, and again sight the original point using a flop sight. Now plunge the scope to its direct position and mark this line of sight on or along side of the previously marked point. If the two points are one and the same, no adjustment is necessary. If the two points are not the same, mark a point one fourth the difference from the last marked point and adjust the vertical wire to that point. This is done by means of the capstan screws on the sides of the cross-hair reticule. After an adjustment is made, another test should be run to verify results.

16–9 THE CARE AND USE OF EQUIPMENT. The following directions are to be observed, to prolong the life of the equipment and promote the accuray of the work:

1. Instruments shall be kept in adjustment at all times. Frequent checks shall be made to see they are in perfect operating condition. If they are out of adjustment, the chief-of-party shall make the corrections to within reasonable limits of accuracy.
2. Instruments and other equipment shall be kept clean at all times. Care shall be exercised in cleaning paint and lacquer surfaces so that they are not scratched or the finish removed during the cleaning operations. Steel tapes and chains shall be cleaned at the end of the day and wiped with an oiled rag to prevent rust. Instuments and other equipment shall not be left exposed to rain or snow. If it is necessary to work in rain or snow, protect the instruments with a piece of light canvas or other suitable covering, and clean and dry immediately after the work is completed.
3. Protect the lenses of the telescope from dust and moisture by placing the cap over the end and closing the eyepiece.
4. Instruments shall be carefully oiled when necessary. Heavy oil shall never be used on any part of the instrument. Fine watch oil shall be used sparingly when necessary.
5. Whenever instruments become damaged or are in need of repairs, the chief-of-party shall notify his immediate superior, who shall make arrangements for replacements and the necessary repairs. If any of the protecting glasses become broken, the plates should be immediately clamped and the instrument sent in for repairs. Instruments should never be used with broken glasses.
6. Great care shall be used to avoid excessive strains to any of the vital parts of surveying instruments. They shall never be forced into place in their carrying cases, nor forcibly removed.
7. In placing instruments on their tripods, care shall be taken to protect the threads. Support the weight of the instrument by holding it by the lower plates and turning it backward until a slight click is heard, indicating

the instrument is in the proper position for the threads to mesh. Never handle the instrument by one standard and always keep the threads clean.

8. In removing instruments from their tripods, wrenches or other tools shall never be used. If the head sticks so that it cannot be removed by hand, hot cloths shall be applied to the base plates.
9. Clamps, level screws, and other adjustments shall never be so tight that they will be strained. They shall be set firmly, but never tight.
10. The chief-of-party shall check at least once a week to see that his equipment is complete and in good working condition. Lost equipment shall be reported immediately in writing.

16–10 By taking proper precautions, the wear and tear on instruments may be greatly reduced, and frequently permanent damage to some part of an instrument may be avoided. It must be remembered that there are many parts of an instrument which, if once damaged, cannot be restored to their original efficiency. The following should be avoided:

1. When removing an instrument from its carrying case, it should not be grasped or lifted by the telescope, horizontal axis, standards or circle. The proper way being to place the ends of the fingers under the lower plates and gently ease the instrument from the box.
2. Do not carry instruments over the shoulder except in open country, where it is impossible for them to strike against objects of any kind. Through timber, brush or any place where they may be damaged, carry under the arm with the instrument ahead.
3. Do not leave an instrument unguarded in a street, road, pasture or in proximity to blasting operations.
4. Do not carry an instrument on its tripod or in its carrying case with the telescope or plates free to move. Lightly clamp the principal motions to prevent wear on the center.
5. Do not leave steel tapes or chains exposed to damage from passing cars. Don't "pull" kinks out of steel tapes or chains. This is a sure way of breaking them.
6. Do not use steel or metallic tapes or chains in close proximity to electric wires. Serious injury or death may result by violating this rule.
7. Do not leave sight or level rods standing in a corner. They should be placed in a hanging position, or laid on a flat surface, so there will be no twisting or warping of the rods.
8. Do not let a "high" level rod down on the run, or lean against a tree or leave it in any position where it is liable to fall.
9. Do not use rods, axes, plumb bobs, or brush hooks, for digging or pounding, or any other purpose except for which they were intended. Axes and brush hooks should be kept clean and sharp.
10. Do not lay rules, tapes, plumb bobs, Locke levels, or other small equipment down. When through with their use, replace in their cases or pockets on your person. It is advisable before moving from a location for each man to check his equipment to see that nothing is left behind.

16–11 Following is a list of equipment and supplies:

EQUIPMENT:

Personnel Car
Transit
Tripods
Wye Level
Level Rods
Sight Rods
Targets
Clinometers
Gradeometers
100′ Steel Chains
50′ Steel Tape in Cases
100′ Steel Tape in Cases
50′ Metallic Tape in Cases
Locke Levels and Cases
Plumb Bobs and Cases
6′ Rule
Hand Axes
Large Axes
Sledgehammers
Brush Hooks
Kit Bags
Tape Repair Outfit
Straight Edges
Engineer's Scales
Ives & Kissam—Highway Curves
Allens Railroad Curves and Earthwork
Allens Field and Office Tables
U. S. Department of Agriculture Handbook of "Transition Curves for Highways."
Butts Field Book
Screw Drivers
Adjusting Pins
Reading Glasses
Protractors
Triangles
Solar Eye Pieces
Chaining Pins
Caution Signs and Flags
Flagmen Vests

SUPPLIES:

Metallic Tape Fillers—Exchangeable
Steel Tape Fillers—Exchangeable
Glasses for Locke Levels
Plumb Bob String
Plumb Bob Points
Stakes
Survey Tacks
Crayon (Blue, Yellow, Red)
Red Cloth Flags
Notebooks
Stamps
Envelopes
Pen Holders
Stationery

CHAPTER SEVENTEEN

REPORTS—FORMS

17–1 List of commonly used forms:

Form No.	Description
55	Traveling expense voucher
55-S	Record of operation—Employees personal car
204	Receipts for traveling expense account
OA330	Application for leave of absence
401	Survey charges
401-I	Instructions for compiling information and cost on form 401 survey charges
408	Department of Highway specifications
409	Department of Highway specifications for plain and fabricated steel structures
413	Grade sheet
419 or 419-A	Daily survey report card
428	Field survey notebook
436	Report—Detail Bridge Inspection
444	Bridge data sheet with recommendations
473-F	Azimuth by Altitudes of the Sun
488-A	Iron-Steel or Timber Bridge Record
488-B	Concrete or Masonry Bridge Record
488-C	Supplemental Bridge Record
601	Fuel, Oil, and Anti-freeze receipt
614	Department equipment emergency repairs
627	Equipment accident report
629	First aid report
633	Receipt, Maintenance hand tool
683	Agreement for automibiles and light trucks (private car rental)
701	Shipping tag
727-A	Envelopes (mailing)
805	Record of equipment operation
807	Property survey
816	Report of stolen property to state police
924	Certification of attendence
LIBC344	Employers report of industrial injury

17–2 **Form 401, Surveys charges;** This form is to be used for two separate operations:

1. Show the weekly attendance record of each employe of the corps. (For additional instructions, refer to Form 401-I, "Instructions for compiling engineering costs.") The form under this function must be submitted to the district office weekly.

2. The other function of Form 401 is to list mileage, gas, oil, and anti-freeze according to projects as listed on Form 805, "Record of equipment operation."

17–3 Form 805, Record of Equipment Operation:

This form is a daily record of equipment pertaining to miles operated and gasoline, oil, and anti-freeze used during the month. The gasoline, oil, and anti-freeze entered on the Form 805 shall be taken from the Form 601, (Fuel, Oil, and Anti-freeze receipt); Form 805 must be submitted monthly to the district office with the Forms 601 and 401 attached (stapled) to the Form 805.

17–4 Form 204, Receipt for Lodging and/or Meals.

All receipts should show the place and post office address where the expense was incurred. The information on the face of a receipt for subsistence must show the daily or weekly rate paid and shall include the dates on which the first and last service was rendered and any check-outs not included in the total amount paid. This information shall be furnished by the person preparing the receipt. The itemization on the back of the receipt by the employe is to show the items applicable each day. You are not required to show the individual amounts but the itemizing must be made as follows: The dates should be shown in numerical order and headings inserted in columnar order to cover only the items for which the receipt applies, such as Breakfast, Lunch, Dinner and Lodging, or just Lodging, and then a check mark (√) placed opposite the date and under the headings for each meal taken, and the nights you occupied the room. If for any reason of your own volition, you did not stay in the room overnight or did not take a particular meal which you were compelled to pay for due to weekly rate, you shall show a horizontal line(—) opposite the date and in the column for that item, and note at the bottom of the reverse side of the receipt the information "No check-outs allowed on the rate paid," if this is the actual circumstance, otherwise the amount of the items paid for but not taken shall be deducted on the statement by the employee from the total of the receipt. The legend used for the itemization must be indicated under the listing as follows, since no receipt will be approved by the Fiscal Officers without it:

√ Meals taken or Room occupied

— Meals not taken or Did not stay in Room overnight. The listing shall be started by placing the following headings "B-L-D-Ldg.," at the bottom of the reverse side of the receipt and continue the itemization lengthwise by dates, which allows the information to be easily checked after the receipt is attachd to the statement.

17–5 Form 419-A, Daily Survey Report.

This daily survey report is in the form of a postcard and it is essential that all information be shown and the cards mailed promptly at the end of each days work to the district engineer. Any absence of personnel together with the reason shall be noted on the address side of the card.

17–6 Form 55, Instructions to Corpsmen on the Preparation of Expense Statements.

1. Form 55 is a combined Code Sheet and Expense Account. This voucher is a form required by the fiscal officers (chief clerk) and is necessary for the issuance of expense checks. The rules must be strictly followed. The form must be made in triplicate.

2. The inclusive dates must be shown at the top of the statement on the front and reverse side regardless of whether expenses cover the entire period or not.

3. All figures must be clear and distinct using a ball point pen or type, and nothing unnecessary should be written on the face of the statement. When it becomes necessary to change a figure, eradicate the incorrect one and insert the correct one; no ditto marks are allowed on actual expenses or mileage.

4. Only actual and reasonable charges, necessarily incurred for the benefit of the Commonwealth, shall be considered.

5. Expenses for trips home, to voting residence for election or registration, or to any other points not in direct execution of Department work are personal expenses and cannot be allowed.

6. Employes living close to their assignment will be expected to live home. No subsistence will be approved when incurred at the residence of an employe, but a change of residence may be recorded at any time by having the district engineer and district clerk personally approve the new residence as shown on the Expense Statement. The Central Office must also be notified of the change.

7. The amounts shown for meals shall not include lunches between meals, double meals, double desserts, midnight or bed-time meals or other personal expenditures.

8. Employes are not permitted to make trips on Department time for the purpose of inquiring about or securing their pay or expense checks, and telephone expense incurred for this purpose must not be included on the expense statement.

9. Employes will not be permitted to submit expense statements covering items incurred as a result of working overtime at headquarters, such as meals at headquarters or transportation between their homes and headquarters.

10. A general statement shall be given under "Remarks" explaining the necessity for incurring the expense, also full details of any unusual charges. The explanation on all Statements should begin similar to the following:

"Expenses incurred in connection with my duties
as ..... on ..... on route ....."
Show Kind of work Show Rt. or Rts.

11. Expense incurred on Saturday afternoons, Sundays, or holidays, must be fully explained under "Remarks." When absent from assignment on any day, or over a week-end or Holiday, or when on sick leave, vacation, or absent without pay, no expenses are allowed, as these are personal items. When an employe leaves the job of his own volition, such as going to his home, his expenses cease when he leaves the assignment and do not begin again until he works, except when permission has been secured from the Supervisor for the employe to return for lodging the night before. The distance from the employe's home and the transportation used shall govern such approvals, which should be explained under "Remarks." When absent from the assignment overnight, breakfast on the following morning is disallowed.

12. Gasoline for State owned equipment should be secured at a Maintenance Building wherever possible. The next alternative is an approved service station of a company having a State contract.

13. All Expense Statements for travel out of the State must have the personal approval of the Governor in advance. When it becomes necessary for an employe to incur expense in travel outside Pennsylvania, while in the prosecution of

Department business, it is necessary to show the purpose of the trip under "Remarks", even in cases where it is advisable to leave the State in order to take the quickest or cheapest route between points in Pennsylvania.

14. Be sure the proper authorization and operation numbers are shown on the coding data section. Different Authorization and coding must be separated by one space. If more than three are used, tape a second coding section on all three Forms 55. Breakdown of costs appear **only on original form.** Coding must be placed on all 3 copies. Only one total per line is permitted. The first Form 55 must be original front and reverse. The employe's name shown at the top of sheet must be legible and must correspond with the signature at the bottom. Do not show route numbers on the Code Section. Federal Aid project numbers however, must be shown under the "To" column, if no Federal Aid number then the legislative route number.

15. Coding to be used under column headed Initials of carrier are S. C. for state equipment, P. A. for Personal Auto. N. C. for riding with another employe.

16. In order to avoid unnecessary delay be sure your Statement is correct in every detail and submit it so as to reach the District Office WITHIN three (3) calendar days ater the close of the period. All receipts required in accordance with the provisions of the "Travel Expense Manual", must be attached to the first copy. All totals must be completed.

17. Under Remarks, explain in full for all meals; Breakfast and Supper meals must state time of departure and return, including miles from home or official headquarters. If Personal car (P. A.) is used, the name and type of car, manufacturer's serial number, and license number must appear; for State owned equipment (S. C.), the equipment number must appear. If riding with another Employe (N. C.) the driver of said car must appear.

18. A breakdown of costs for each Federal Aid project, or Legislative Route number, (if not a Federal Aid project) must be shown under "Remarks" of the third copy only.

19. Employes should realize the responsibilities incurred in certifying to the truth and correctness of their Expense Statements, as they will be held strictly accountable for the certification. Irregularities shall be a just cause for dismissal, and the offender shall be dealt with according to law.

20. All employes who approve Expense Statements should instruct employes under their supervision in the rules which prescribe and limit the amounts and items for which they will be reimbursed and in the proper preparation of their Expense Statement. The official who approved expenses is responsible for the truth and exactness of all expenditures charged. This necessitates careful consideration of each statement before approval. No official is permitted to approve his own Expense Statement; the personal approval of his immediate superior is necessary. When, in the opinion of the official approving the statement, charges appear unreasonable and are not satisfactorily explained, they should be reduced.

Survey Corps' Expenses

21. A survey corps is entitled to necessary traveling and subsistence expenses actually incurred while executing corps duties, except at residence. Survey Corps shall endeavor to secure subsistence at private boarding houses near the job, using hotels or motels only in emergencies, always endeavoring to secure

reduced rates if the corps is expected to stay at one place for any length of time.

22. Daily transportation to and from the job by automobile shall be considered only upon approval of the District Engineer. To minimize transportation costs, the corps shall carry their lunch into the field when possible.

Form 55-S, Record of Operation—Employe's Personal Car.

This form is to be prepared in duplicate, Speedometer readings are to be posted each day. The Federal Aid project number, or legislative route number, (if no Federal Project) must be listed each day under the heading of "Purpose of Trip," total mileage must be posted at bottom of Form for the period. All other headings are self explanatory and must be filled in completely.

CHAPTER EIGHTEEN

CONSTRUCTION ITEMS
and Basis Upon Which Payment is Made

18–1

Item	*Ref. to Specs*	Basis of Measurement: Cubic Feet	Cubic Yards	Square Feet	Square Yards	Lineal Feet	Pounds	Tons	Each	Refer to Notes
Expansion Material around or along Structures	1. 4.7									a
Rail Channel Filler	1. 4.8									a
Clearing and Grubbing	3. 1.4									b
Class 1 Excavation	3. 2.4		X							
Class 2 Excavation	3. 3.4		X							
Embankment	3. 4.4		X							c
Borrow Excavation	3. 5.4		X							
Foreign Borrow Excavation	3. 5.4		X							
Waste	3. 2.1(6)		X							
Overhaul	3. 6.1		X							
Subgrade	3. 7.4			X						d
Shoulders	3. 8.4					X				
Subgrade Aggregate	3. 9.4		X							e
Sub-Base	3.10.4		X							e
Plain Cement Concrete Base Course	4. 1.4(1)			X						
Cement Concrete Header Curb	4. 1.4(2)					X				
Crushed Stone Base Course	4. 2.4(1)			X						
Calcium Chloride	4.2.4(2)-9. 1.4(3)							X		
Crushed Aggregate Base Course	4. 3.4			X						
Native Stone Base Course	4. 4.4			X						
Reconstructed Base Course	4. 5.4		X							e
Selected Material Surfacing	4. 9.4		X							
Reinforced Cement Concrete Pavement	5. 1.4(2)			X						
Plain Cement Concrete Pavement	5. 1.4(1)			X						
Plain Cement Concrete Wearing Surface for Bridge Floors	5. 2.4			X						
Vitrified Brick Pavement	5. 3.4			X						
Relaid Block Pavement	5. 4.4			X						
Bituminous Surface Course JA-1	5. 8.4			X				X		
Bituminous Surface Course ID-2	5. 9.4			X				X		

18–1 (Cont'd.)

Item	*Ref. to Specs*	Basis of Measurement								
		Cubic Feet	Cubic Yards	Square Feet	Square Yards	Lineal Feet	Pounds	Tons	Each	Refer to Notes
Bituminous Surface Course FJ-1	5.10.4							X		
Bituminous Surface Course HSD	5.11.4				X			X		
Bituminous Surface Course HE	5.14.4				X			X		
Bituminous Surface Course HC	5.15.4				X			X		
Bituminous Surface Course DP-1	5.20.4				X					
Bituminous Surface Course CP-2	5.21.4				X					
Bituminous Surface Course FB-1	5.22.4				X					
Bituminous Surface Course FB-3	5.23.4				X					
Bituminous Surface Course AT-1	5.24.4				X					
Class AA Concrete	6. 1.4(1)		X							f
Class A Concrete	6. 1.4(1)		X							f
Class B Concrete	6. 1.4(1)		X							f
Reinforcement (Structures)	6. 1.4(2)						X			
Annealed Iron Wire (Structures)	6. 1.4(2)						X			
Plain and Fabricated Structural Steel	6. 1.4(2)						X			
Reinforcement Bar Frames	6. 1.4(2)						X			
Steel Wire Fabric or Expanded Metal Mesh	6. 1.4(2)						X			
Stone Backfill	6. 1.4(3)		X							
Piles (Test Piles)	6. 2.4(4)(1)									E
Piles (Bearing Piles)	6. 2.4(4)(2)					X				
Metal Points for Piles (When specified)	6. 2.4(3)									a
Foundation Columns	6. 3.4					X				
Ties for Grillage	6. 4.4								X	
Ashlar Rubble Masonry	6. 5.4		X							
Cement Rubble Masonry	6. 6.4		X							
Dry Rubble Masonry	6. 7.4		X							
Brick Masonry	6. 8.4		X							
Repointed Masonry	6. 9.4				X					
Waterproofing (Two-coat Painted)	6.10.4(1)									a
Waterproofing (Membrane)	6.10.4(2)				X					
Temporary Bridges and Approaches	6.11.4									b
Removal of Existing Bridges	6.12.4									h
Class B Cement Concrete Paving for Stream Beds	6.13.4		X							

18–1 (Cont'd.)

Item	*Ref. to Specs*	Basis of Measurement: Cubic Feet	Cubic Yards	Square Feet	Square Yards	Lineal Feet	Pounds	Tons	Each	Refer to Notes
Plain and Mortared Rubble Paving for Stream Beds	6.14.4		X							
Steel Beam Bridge Flooring	6.15.4			X						
Pressure Mortar Pointing and Surfacing	6.16.4				X					
Name and Bench Mark Plates	6.17.4									i
Cement Concrete Slope Wall	6.18.4		X							
Plain and Mortared Stone Slope Wall	6.19.4		X							
Tree Walls	6.20.4		X							j
Reinforced Concrete Cribbing	6.21.4(1)	X								
Metal Cribbing	6.21.4(2)			X						
Foundation Blocks	6.21.4(3)		X							
Pipe Culverts (New)	6.25.4(1)					X				
Relaid Pipe Culverts	6.25.4(2)					X				
Metal Plate Pipe Culverts	6.26.4(1)					X				
Metal Plate Arches	6.26.4(2)					X				
Corrugated Metal Pipe-Arch	6.27.4					X				
Asphalt Coated Corrugated Metal Pipe-Arch	6.27.4					X				
Endwalls (except "F" types)	6.28.4		X							
Inlets, Manholes and Type "F" Endwalls	6.28.4								X	
Reset Miscellaneous Structure Castings	6.29.4								X	
Rebuilt Miscellaneous Structures	6.30.4					X				n
Underdrain	7. 1.4					X				
Foundation Underdrain	7. 1.4					X				
Underdrain Outlets	7. 2.4					X				
Stone Underdrain	7. 3.4(1)					X				
Stone Foundation Underdrain	7. 3.4(2)					X				
Subgrade Drains	7. 4.4					X				
Plain Cement Concrete Gutter	7. 5.4				X					
Plain and Reinforced Cement Concrete Curb Gutter	7. 6.4				X					
Plain and Mortared Rubble Gutter	7. 7.4				X					
Vitrified Brick Gutter	7. 8.4				X					
Repaved Gutter	7. 9.4				X					
Covered Gutters	7.10.4									k
Plain Cement Concrete Curb	1.15.4					X				
Armored Cement Concrete Curb	7.16.4					X				

18–1 (Cont'd.)

Item	Ref. to Specs	Basis of Measurement: Cubic Feet	Cubic Yards	Square Feet	Square Yards	Lineal Feet	Pounds	Tons	Each	Refer to Notes
Integral Cement Concrete Curb	7.17.4					X				
Stone Curb	7.20.4					X				
Reset Curb	7.21.4					X				
Redressed, Reset Stone Curb	7.22.4					X				
Cement Concrete Sidewalks	7.25.4				X					l
Guard Fence	7.30.4(1)					X				
End Anchorages	7.30.4(2)								X	
Guard Posts	7.31.4								X	
Topsoil Stockpiled	8. 1.4									a
Topsoil Furnished and Placed	8. 2.4				X					
Placing Stockpiled Topsoil	8. 3.4				X					
Seeding	8. 4.4				X					
Fertilizer	8. 4.4						X			
Mulching	8. 5.4				X					
Maintenance of Traffic	9. 1.4									m
Permanent Barricade						X				

NOTE: Under certain conditions the basis of payment changes and the particular Section of the Specifications as indicated above should be referred to.

The Special Provisions in the Proposal should be carefully reviewed to ascertain if the basis of payment of any item of the Specifications has been changed which would affect the above tabulation.

18–2 Reference Notes

"a"—Included in unit price of other items of the construction.

"b"—Lump sum if such an item is provided in the proposal, otherwise it is considered incidental to other items of work.

"c"—Not payable directly but as a subsidiary obligation under other items of the contract.

"d"—Subgrade shall not be paid for until the base course or pavement has been constructed thereon. Subgrade will not be allowed in connection with the placing of selected material surfacing or in areas occupied by sub-base.

"e"—Measured loose in the container in which it is transported.

"f"—The contract unit price shall include masonry facing, premoulded expansion joint material, zinc sheets, lead sheets, copper flashing, two-coat painted waterproofing, photographs, drainage and weep holes, formation of all joints and the placing of all pipes, conduits, anchors, bolts, metal grillages and similar materials unless otherwise specified.

"g"—Test Piles will be paid for at the contract lump sum price, except that additional test piles ordered by the engineer and driven, in excess of the num-

ber shown in the proposal or extensions to test piles ordered by the engineer, will be paid for as bearing piles.

"h"—When an item is included in the proposal for the removal of the existing bridge, the lump sum price will include the removal of both the superstructure and substructure. When a lump sum item is provided in the proposal for the removal of the existing bridge superstructure only the removal of the substructure will be paid for as Class 1 or Class 2 excavation, as the case may be. When no item is provided in the proposal for the removal of the existing bridge, the existing substructure and masonry superstructure shall be removed at the contract unit price for Class 1 or Class 2 excavation as the case may be. The payment for the removal of the steel or timber superstructure will be included in the lump sum price for clearing and grubbing.

"i"—Furnished by the Department and cost of setting included in cost of structure.

"j"—Exclusive of reinforcement and aggregate.

"k"—Covers will be paid for on a square foot basis. The basin of the gutter will be paid for as cubic yards of Class "A" concrete.

"l"—Sidewalks integral with the superstructure of a structure will be paid at the unit price per cubic yard for the class of concrete specified. See Section 6.1.4(1) of the Specifications.

"m"—Maintenance of traffic during the temporary suspension of work will be paid for at the contract lump sum price, or if there is no such item at an agreed price, or the engineer to perform such work with Department Forces under Method Number 1.

Under Method Number 2, payment will be made for materials as designated in Section 9.1.4(2) at unit price per cubic yard.

Under Method Number 3, calcium chloride will be paid for at an agreed price per ton and road oils will be paid for at an agreed price per gallon.

"n"—Vertical foot.

Table 18–1 CONVERSION TABLES

Avoirdupois Weight

27 11/32	grains	= 1 dram	2,000	lbs.	= 1 short ton
16	drams	= 1 ounce	2,240	lbs.	= 1 long ton
16	ounces	= 1 pound			

Dry Measure

2	pints	= 1 quart	4	pecks	= 1 bushel
8	quarts	= 1 peck	36	bushels	= 1 chaldron

Liquid Measure

4	gills	= 1 pint	31½	gallons	= 1 barrel
2	pints	= 1 quart	2	barrels	= 1 hogshead
4	quarts	= 1 gallon			

Table 18–1 (Cont'd.)

Circular Measure

60 seconds	= 1 minute	30 degrees	= 1 sign
60 minutes	= 1 degree	90 degrees	= 1 quadrant
4 quadrants	= 12 signs	360 degrees	= 1 circle

Long Measure

12 inches	= 1 foot	40 rods	= 1 furlong
3 feet	= 1 yard	8 furlongs	= 1 statute mile
5½ yards	= 1 rod	5280 feet	= 1 statute mile

1 nautical mile = 6080.204 ft. or 1.1516 statute miles

1 league = 3 nautical miles or 18240.613 ft.

1 palm	= 3 inches	1 cubit	= 18 inches
1 hand	= 4 inches	1 Bible cubit	= 21.8 inches
1 span	= 6 inches		

Surveyor's Measure

7.92 inches = 1 link
25 links = 1 rod = 16.5 feet
4 rods = 1 chain = 66 feet
10 sq. chains = 1 acre
36 sq. miles (6 miles sq.) = 1 township
1 mile = 320 rods = 8 furlongs

Square or Land Measure

144 sq. inches	= 1 sq. ft.	160 sq. rods	= 1 acre
9 sq. feet	= 1 sq. yd.	640 acres	= 1 sq. mile
30.25 sq. yds.	= 1 sq. rod	1 acre	= 208.71 ft. sq.

Cubical Measure

1728 cubic inches	= 1 cubic foot	128 cubic feet	= 1 cord
27 cubic feet	= 1 cubic yard		

Ordinary Units

1 cu. ft. of water at 39.1° F. = 62.425 lb.
1 U. S. gallon = 231 cu. in.
1 Imperial gallon = 277.274 cu. in.
1 cubic foot of water = 1728 cu. in.
= 7.480519 U. S. gallons
= 6.232103 Imperial gallons
= 62.4250 pounds
1 U. S. gallon = 231 cu. in.
= 0.133681 cu. ft.
= 0.83311 Imperial gallons
= 8.245 pounds
1 barrel = 31.5 gallons = 4.21 cu. ft.
1 U. S. bushel = 1.2445 cu. ft.
1 fluid ounce = 1.8047 cu. in.

Table 18–1 (Cont'd.)

Metric and U. S. Equivalents

The metric unit of length is the meter = 3.28 feet
The metric unit of square measure is the square meter = 10.76 sq. ft.
The metric unit of volume is the cubic meter = 35.3 cu. ft.
The metric unit of weight is the gram = 15.43 grains
The metric unit of liquid measure is the liter = 0.264170 U. S. liquid gallon

The following prefixes are used for sub-divisions and multiples:

Milli $= \frac{1}{1000}$	Deka = 10
Centi $= \frac{1}{100}$	Hecto = 100
Deci $= \frac{1}{10}$	Kilo = 1000
unit as above = 1	Myria = 10,000

Length

1 inch	=	2.5400 centimeters
1 foot	=	0.3048 meters
1 statute mile	=	1.60935 kilometers
1 nautical mile	=	1.853 kilometers
1 centimeter	=	0.39370 inches
1 meter	=	3.28 feet
1 kilometer	=	3280.83 feet = 0.62137 mile

Square Measure

1 square centimeter	=	0.155	square inches
1 square meter	=	10.76	square feet
	=	1.196	square yards
1 hectare	=	2.47	acres
1 square kilometer	=	0.386	square mile
1 square inch	=	6.45	square centimeters
1 square foot	=	0.0929	square meter
1 square yard	=	0.836	square meter
1 acre	=	0.405	hectares
1 square mile	=	2.59	square kilometers

Volume

1 cubic inch	=	16.387	cubic centimeters
1 cubic foot	=	0.0283	cubic meter
1 cubic yard	=	0.765	cubic meter
1 cubic centimeter	=	0.0610	cubic inches
1 cubic meter	=	35.3	cubic feet
	=	1.308	cubic yards

Table 18–1 (Cont'd.)

Liquid Measure

1 liter	=	61.0233378	cubic inches
	=	0.035314	cubic feet
	=	0.264170	U. S. liquid gallon
	=	0.2201	Imperial gallon
1 millimeter	=	0.0338	liquid ounce (U. S.)
1 U. S. liquid ounce	=	29.57	millimeters
1 U. S. liquid quart	=	0.946	liter
1 U. S. liquid gallon	=	3.785	liters
1 Imperial gallon	=	4.543	liters

Weight

1 gram	=	15.43	grains
	=	0.0353	avoirdupois ounce
1 kilogram	=	2.205	avoirdupois pounds
1 metric ton	=	0.9842	long ton
	=	1.102	short tons
1 avoirdupois ounce	=	28.35	grams
1 avoirdupois pound	=	0.4536	kilograms

18–3 PROPERTIES OF A CIRCLE

Radius	=	Circumference	x 0.159155
	=	Square Root of Area of Circle	x 0.56419
Diameter	=	Circumference	x 0.31831
	=	Square Root of Area of Circle	x 1.12838
Circumference	=	Diameter	x Pi.
	=	Square Root of Area of Circle	x 3.5446
Area	=	Radius Squared	x Pi.
	=	Diameter Squared	x 0.7854
	=	Circumference Squared	x 0.07958

Pi. = 3.14159265 $Pi.^2$ = 9.8696044 Square Root of Pi. = 1.7724538

Log. Pi. = 0.4971499 $\frac{1}{Pi.}$ = 0.3183001

(In general practice use only to four (4) decimal places.)

18–4 MISCELLANEOUS EQUIVALENTS

Side of a Square equal in area to a Circle = Diameter x 0.8862.
Diameter of a Circle equal in area to a Square = Side of square x 1.12838.
Diameter of a Circle of equal periphery to a Square = Side of square x 1.27324.
Side of a Square of equal periphery to a Circle = Diameter x 0.78540.
Surface of a Sphere = $(Diameter)^2$ x Pi.
Area of a Regular Polygon = Sum of sides x ½ perpendicular distance from center to sides.

Area of a Cylinder = Circumference x height + areas of both ends.
Side of a Square inscribed in a Circle = Diameter x 0.70711.
Diameter of a Circle circumscribed about a Square = Side of square x 1.41421.
Side of a Hexagon inscribed in a Circle = Diameter x 0.500.
Diameter of a Circle inscribed in a Hexagon = Side of Hexagon x 1.7321.
Side of an Equilateral Triangle inscribed in a Circle = Diameter x 0.866.
Diameter of a Circle inscribed in an Equilateral Triangle = Side of Triangle x 0.57735.
Area of Ellipse = Long Diameter x Short Diameter x 0.7854.
Volume of a Sphere = $(\text{Diameter})^3$ x 0.5236.
Side of a Cube equal in volume to a Sphere = Diameter x 0.806.
Length of a Cylinder equal in volume to a Sphere with same diameter = Diameter x 0.6667.
Volume of a Prism (Right or Oblique) = Area of base times perpendicular height.
Volume of a Cylinder = Area of section at right angles to sides times length of side.
Volume of Segment of a Sphere = (Height squared plus three times the square of the radius of the base) x (height x 0.5236).
Volume of Frustrum of a Cone = (The square root of the areas of the two ends multiplied) + (area of the ends) x ⅓ of the altitude.
Volume of Pyramid or Cone = Area of base x ⅓ perpendicular height.
Doubling the diameter of a pipe increases its capacity four times.
0° Centigrade = 32° Fahrenheit. Each 5° increase Centigrade = a 9° increase Fahrenheit, as 5° C. = 41° F.
1° Fahrenheit = 0.5556° Centigrade.
1° Centigrade = 1.8° Fahrenheit.

18–5 HEADS OF WATER IN FEET IN COMPARISON WITH PRESSURES IN VARIOUS UNITS

One foot of water at 39.1° F. = 62.425 pounds per square foot
= 0.4335 pounds per square inch
= 0.0295 atmosphere
= 0.8826 inch of mercury at 30° F.
= 773.3 feet of air at 32° F. and atmospheric pressure

One pound on the square foot, at 39.1° F. = 0.01602 foot of water.
One pound on the square inch, at 39.1° F. = 2.307 feet of water.
One atmosphere of 29.922 inches of mercury = 33.9 feet of water.
One inch of mercury at 32° F. = 1.133 feet of water.
One foot of air at 32° F. and 1 atmosphere = 0.001293 foot of water
One foot of average sea water = 1.026 feet of pure water.
One foot of water at 62° F. = 62.355 pounds per square foot.
= 0.43302 pound per square inch.
One pound of water on a square inch at 62° F. = 2.3094 feet, height of a column of water.
1 atmosphere at sea level (32° F.) = 14.697 lbs. per sq. in.
= 29.921 in. of mercury.
1 inch of mercury (32° F.) = 0.49119 lb. per sq. in.

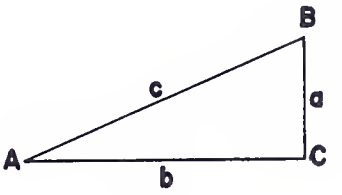
To find the pressure in pounds per square inch at the base of a column of water, multiply the height of the column in feet by 0.433. (Approximate method.)

1 C.F.S. = cubic feet per second, or second feet
G.P.M. = gallons per minute
C.F.S. = 60 cu. ft. per minute
= 86,400 cu. ft. per day (24 hrs.)
= 448.83 U. S. gallons per minute
= 646,317 U. S. gallons per day (24 hrs.)
= 1.9835 acre-foot per 24 hours
= 1 acre-inch per hour (approx.)
= 2446.59 cu. meters per day (24 hrs.)

1 inch depth per hour = 645.33 C.F.S. per sq. mile
1 inch depth per day = 26.889 C.F.S. per sq. mile
1 U. S. G.P.M. = 1440 U. S. gallons per day
1 million U. S. gallons per day = 1.5472 C.F.S.
1 cu. ft. ice at 32° F. = 57.50 lbs.
1 cu. ft. ice at 32° F. = 1.0855 cu. ft. water at 32° F
1 lb. ice at 32° F. = 0.0174 cu. ft.

Figure 18–1

TRIGONOMETRIC FUNCTIONS



$$\text{Sin A} = \frac{a}{c} = \text{Cos B}$$

$$\text{Cos A} = \frac{b}{c} = \text{Sin B}$$

$$\text{Tan A} = \frac{a}{b} = \text{Cot B}$$

$$\text{Cot A} = \frac{b}{a} = \text{Tan B}$$

$$\text{Sec A} = \frac{c}{b} = \text{Cosec B}$$

$$\text{Cosec A} = \frac{c}{a} = \text{Sec B}$$

$$\text{Vers A} = \frac{c-b}{c} = \text{Covers B}$$

$$\text{Exsec. A} = \frac{c\text{-}b}{b} = \text{Coexsec B}$$

$$\text{Covers A} = \frac{c-a}{c} = \text{Versin B}$$

$$\text{Coexsec A} = \frac{c-a}{a} = \text{Exsec B}$$

$$a = c \text{ Sin A} = b \text{ Tan A}$$

$$b = c \text{ Cos A} = a \text{ Cot A}$$

$$c = \frac{a}{\text{Sin A}} = \frac{b}{\text{Cos A}}$$

$$a = c \text{ Cos B} = b \text{ Cot B}$$

$$b = c \text{ Sin B} = a \text{ Tan B}$$

$$c = \frac{a}{\text{Cos B}} = \frac{a}{\text{Sin B}}$$

$$a = \sqrt{(c+b)\,(c-b)}$$

$$b = \sqrt{(c+a)\,(c-a)}$$

$$c = \sqrt{a^2+b^2}$$

$$C = 90° = A + B$$

$$\text{Area} = \frac{ab}{2}$$

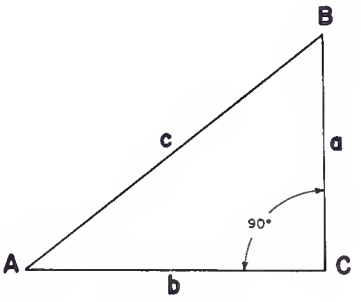
Table 18–2

NATURAL TRIGONOMETRIC FUNCTIONS

Angle	Sin.	Cosec.	Tan.	Cotan.	Sec.	Cos.	
0°	0.000	....	0.000	....	1.000	1.000	90°
1°	0.017	57.30	0.017	57.29	1.000	1.000	89°
2°	0.035	28.65	0.035	28.64	1.001	0.999	88°
3°	0.052	19.11	0.052	19.08	1.001	0.999	87°
4°	0.070	14.34	0.070	14.30	1.002	0.998	86°
5°	0.087	11.47	0.087	11.43	1.004	0.996	85°
6°	0.105	9.567	0.105	9.514	1.006	0.995	84°
7°	0.122	8.206	0.123	8.144	1.008	0.993	83°
8°	0.139	7.185	0.141	7.115	1.010	0.990	82°
9°	0.156	6.392	0.158	6.314	1.012	0.988	81°
10°	0.174	5.759	0.176	5.671	1.015	0.985	80°
11°	0.191	5.241	0.194	5.145	1.019	0.982	79°
12°	0.208	4.810	0.213	4.705	1.022	0.978	78°
13°	0.225	4.445	0.231	4.331	1.026	0.974	77°
14°	0.242	4.134	0.249	4.011	1.031	0.970	76°
15°	0.259	3.864	0.268	3.732	1.035	0.966	75°
16°	0.276	3.628	0.287	3.487	1.040	0.961	74°
17°	0.292	3.420	0.306	3.271	1.046	0.956	73°
18°	0.309	3.236	0.325	3.078	1.051	0.951	72°
19°	0.326	3.072	0.344	2.904	1.058	0.946	71°
20°	0.342	2.924	0.364	2.747	1.064	0.940	70°
21°	0.358	2.790	0.384	2.605	1.071	0.934	69°
22°	0.375	2.669	0.404	2.475	1.079	0.927	68°
23°	0.391	2.559	0.424	2.356	1.086	0.921	67°
24°	0.407	2.459	0.445	2.246	1.095	0.914	66°
25°	0.423	2.366	0.466	2.145	1.103	0.906	65°
26°	0.438	2.281	0.488	2.050	1.113	0.899	64°
27°	0.454	2.203	0.510	1.963	1.122	0.891	63°
28°	0.469	2.130	0.532	1.881	1.133	0.883	62°
29°	0.485	2.063	0.554	1.804	1.143	0.875	61°
30°	0.500	2.000	0.577	1.732	1.155	0.866	60°
31°	0.515	1.942	0.601	1.664	1.167	0.857	59°
32°	0.530	1.887	0.625	1.600	1.179	0.848	58°
33°	0.545	1.836	0.649	1.540	1.192	0.839	57°
34°	0.559	1.788	0.675	1.483	1.206	0.829	56°
35°	0.574	1.743	0.700	1.428	1.221	0.819	55°
36°	0.588	1.701	0.727	1.376	1.236	0.809	54°
37°	0.602	1.662	0.754	1.327	1.252	0.799	53°
38°	0.616	1.624	0.781	1.280	1.269	0.788	52°
39°	0.629	1.589	0.810	1.235	1.287	0.777	51°
40°	0.643	1.556	0.839	1.192	1.305	0.766	50°
41°	0.656	1.524	0.869	1.150	1.325	0.755	49°
42°	0.669	1.494	0.900	1.111	1.346	0.743	48°
43°	0.682	1.466	0.933	1.072	1.367	0.731	47°
44°	0.695	1.440	0.966	1.036	1.390	0.719	46°
45°	0.707	1.414	1.000	1.000	1.414	0.707	45°
	Cos.	Sec.	Cotan.	Tan.	Cosec.	Sin.	Angle

Figure 18–2

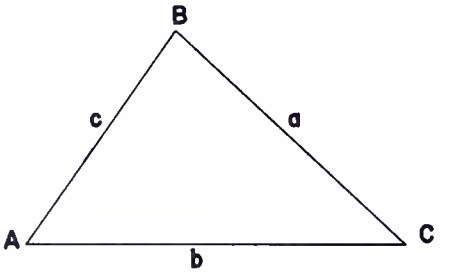
FORMULAS FOR THE SOLUTION OF RIGHT TRIANGLES



Given	Required	Formula
a, A	B, b, c	$B = 90° - A$ $b = a \cot A$ $c = \dfrac{a}{\sin A} = a \csc A$
a, B	A, b, c	$A = 90° - B$ $b = a \tan B$ $c = \dfrac{a}{\cos B} = a \sec B$
c, A	B, a, b	$B = 90° - A$ $a = c \sin A$ $b = c \cos A$
a, b	A, B, c	$\tan A = \dfrac{a}{b}$ $\tan B = \dfrac{b}{a}$, or $B = 90° - A$ $c = \sqrt{a^2 + b^2}$ $c = \dfrac{a}{\sin A} = a \csc A$
a, c	A, B, b	$\sin A = \dfrac{a}{c}$ $\cos B = \dfrac{a}{c}$ or $B = 90° - A$ $b = \sqrt{c^2 - a^2} = \sqrt{(c+a)(c-a)}$ $b = a \cot A$

Figure 18–3

FORMULAS FOR THE SOLUTION OF OBLIQUE TRIANGLES

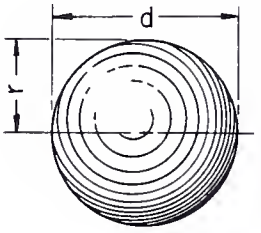


Given	Required	Formulas
a, b, C	A, B, c	$\tan \frac{1}{2}(A-B) = \frac{a-b}{a+b} \cot \frac{1}{2} C$ $A = (90° - \frac{1}{2}C) + \frac{1}{2}(A-B)$ $B = (90° - \frac{1}{2}C) - \frac{1}{2}(A-B)$ $c = \frac{(a-b)\cos \frac{1}{2}C}{\sin \frac{1}{2}(A-B)}$ $c = \sqrt{a^2+b^2-2ab \cos C}$
c, A, B	C, a, b	$C = 180° - (A+B)$ $a = \frac{c}{\sin C} \sin A$ $b = \frac{c}{\sin C} \sin B$
a, b, A	B, C, c	$\sin B = \frac{b}{a} \sin A$ $C = 180° - A - B$ $c = \frac{a}{\sin A} \sin C$
a, b, c $\frac{1}{2}(a+b+c) = s$	A	$\tan \frac{1}{2}A = \sqrt{\frac{(s-b)(s-c)}{s(s-a)}}$ $\cos \frac{1}{2}A = \sqrt{\frac{s(s-a)}{bc}}$ $\cos A = \frac{b^2+c^2-a^2}{2bc}$

Figure 18–4

VOLUMES AND SURFACE AREAS OF GEOMETRICAL SOLIDS

Sphere



Surface $= 4\pi r^2 = 12.5664\, r^2 = \pi d^2$.

Example. $r = 3$.

Surface $= 4 \times 3.1416 \times 3^2 = 113.1$. Ans.

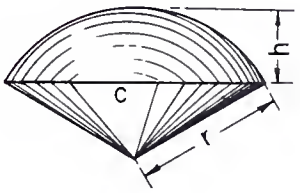
Volume $= \dfrac{4\pi r^3}{3} = 4.1888\, r^3$.

Example. $r = 4$.

Volume $= 4.1888 \times 4^3 = 268.08$. Ans.

Volume $= \dfrac{\pi d^3}{6} = 0.5236\, d^3$.

Sector of Sphere



Total Surface $= \dfrac{\pi r}{2}(4h + c)$;

$c = \sqrt{4\,(2hr - h^2)}$.

Example. $h = 2$; $r = 3$.

Chord $c = \sqrt{4\,(2 \times 3 \times 2 - 2^2)} = 5.657$.

Total Surface $= \dfrac{3.1416 \times 3}{2}\,(4 \times 2 + 5.657)$

$= 64.407$. Ans.

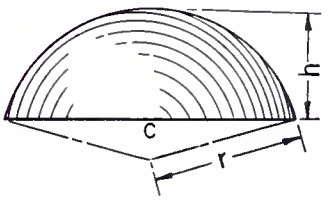
Volume $= \dfrac{2\pi r^2 h}{3} = 2.0944\, r^2 h$

$= \dfrac{2\pi r^2}{3}\left(r - \sqrt{r^2 - \dfrac{c^2}{4}}\right)$

Example. $r = 3$; $h = 2$.

Volume $= 2.0944 \times 3^2 \times 2 = 37.6992$. Ans.

Segment of Sphere



Spherical Surface $= 2\pi rh = \dfrac{\pi}{4}\,(c^2 + 4h^2)$.

Example. $r = 3$; $h = 2$.

Spherical Surface $= 2 \times 3.1416 \times 3 \times 2$

$= 37.6992$. Ans.

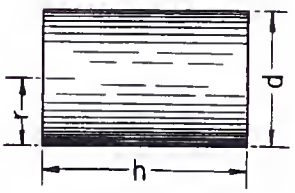
Volume $= \pi h^2\left(r - \dfrac{h}{3}\right) = \pi h^2\left(\dfrac{c^2 + 4h^2}{8h} - \dfrac{h}{3}\right)$

Example. $h = 2$; $r = 3$.

Volume $= 3.1416 \times 2^2\left(3 - \dfrac{2}{3}\right) = 29.3216$ Ans.

Cylinder

c = circumference.



Volume $= \pi r^2 h = 0.7854 d^2 h$

$= \dfrac{c^2 h}{4\pi} = 0.0796\, c^2 h$

Example. $d = 3$; $h = 6$.

Volume $= 3.1416 \times \left(\dfrac{3}{2}\right)^2 \times 6 = 42.4116$ Ans.

Cylindrical surface $= \pi dh = 3.1416\, dh$.

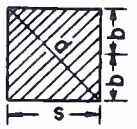
Total surface $= 2\pi r(r + h)$.

Example. $r = 3$; $h = 7$

Total surface $= 3.1416 \times 3\,(2 \times 7 + 3)$

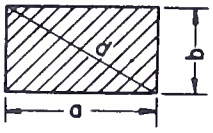
$= 160.2216$ Ans.

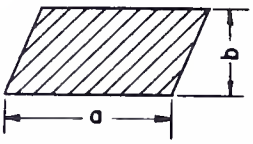
Figure 18–4 (Cont'd.)



Square

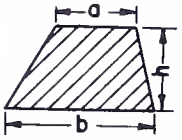
Diagonal $= d = s\sqrt{2}$.
Area $= s^2 = 4b^2 = 0.5d^2$.
Example. $s = 6$: $b = 3$. Area $= (6)^2 = 36$ Ans.
$d = 6 \times 1.414 = 8.484$ Ans.





Rectangle and Parallelogram

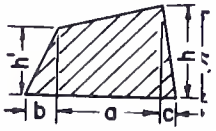
Area $= ab$ or $b\sqrt{d^2 - b^2}$
Example. $a = 6$: $b = 3$.
Area $= 3 \times 6 = 18$ Ans.



Trapezoid

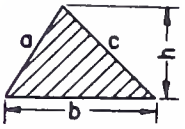
Area $= \frac{1}{2}h\,(a + b)$
Example. $a = 2$; $b = 4$; $h = 3$.
Area $= \frac{1}{2} \times 3\,(2 + 4) = 9$. Ans.

Trapezium



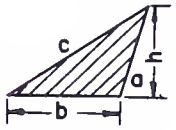
Area $= \frac{1}{2}\,[a\,(h + h^1) + bh^1 + ch]$
Example. $a = 4$; $b = 2$; $c = 2$; $h = 3$; $h^1 = 2$.
Area $= \frac{1}{2}\,[4\,(3 + 2) + (2 \times 2) + (2 \times 3)] = 15$.
Ans.

Triangles



Both formulas apply to both figures
Area $= \frac{1}{2}\,bh$.
Example. $h = 3$; $b = 5$.
Area $= \frac{1}{2}\,(3 \times 5) = 7\frac{1}{2}$. Ans.

Area $= \sqrt{S\,(S-a)(S-b)(S-c)}$ when $S = \dfrac{a+b+c}{2}$

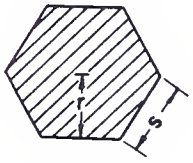


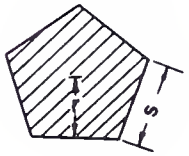
Example. $a = 2$; $b = 3$; $c = 4$.

$$S = \frac{2+3+4}{2} = 4.5$$

Area $= \sqrt{4.5(4.5-2)(4.5-3)(4.5-4)} = 2.9$.
Ans.

Regular Polygons





Area
- 5 sides $= 1.720477\ S^2 = 3.63271\ r^2$
- 6 " $= 2.598076\ S^2 = 3.46410\ r^2$
- 7 " $= 3.633912\ S^2 = 3.37101\ r^2$
- 8 " $= 4.828427\ S^2 = 3.31371\ r^2$
- 9 " $= 6.181824\ S^2 = 3.27573\ r^2$
- 10 " $= 7.694209\ S^2 = 3.24920\ r^2$
- 11 " $= 9.365640\ S^2 = 3.22993\ r^2$
- 12 " $= 11.196152\ S^2 = 3.21539\ r^2$

n = number of sides; r = short radius;
S = width of side; R = long radius.

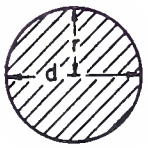
$$\text{Area} = \frac{n}{4}\,S^2 \cot.\frac{180°}{n} = \frac{n}{2}\,R^2 \sin.\frac{360°}{n}$$
$$= nr^2 \tan\frac{180°}{n}$$

Circle

$\pi = 3.1416$; A = area; d = diameter; p = circumference or periphery; r = radius.

$p = \pi d = 3.1416d$. $\quad p = 2\sqrt{\pi A} = 3.54\sqrt{A}$

$p = 2\,\pi r = 6.2832\,r$. $\quad p = \dfrac{2A}{r} = \dfrac{4A}{d}$



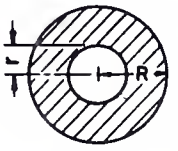
$d = \dfrac{p}{\pi} = \dfrac{p}{3.1416}$ $\quad d = 2\sqrt{\dfrac{A}{\pi}} = 1.128\sqrt{A}$

$r = \dfrac{p}{2\pi} = \dfrac{p}{6.2832}$ $\quad r = \sqrt{\dfrac{A}{\pi}} = 0.564\sqrt{A}$

$A = \dfrac{\pi d^2}{4} = 0.7854d^2$ $\quad A = \dfrac{p^2}{4\pi} = \dfrac{p^2}{12.57}$

$A = \pi r^2 = 3.1416\,r^2$ $\quad A = \dfrac{pr}{2} = \dfrac{pd}{4}$

Figure 18–4 (Cont'd.)



Circular Ring

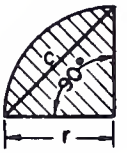
Area $= \pi (R^2 - r^2) = 3.1416 (R^2 - r^2)$

Area $= 0.7854 (D^2 - d^2) = 0.7854 (D - d)(D + d)$

Area = difference in areas between the inner and outer circles.

Example. $R = 4$; $r = 2$.

Area $= 3.1416 (4^2 - 2^2) = 37.6992$. Ans.

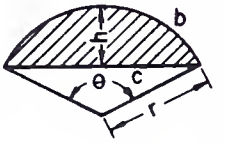


Quadrant

$$\text{Area} = \frac{\pi r^2}{4} = 0.7854\, r^2 = 0.3927\, c^2.$$

Example. $r = 3$. c = chord.

Area $= .7854 \times 3^2 = 7.0686$. Ans.



Segment

b = length of arc. θ = angle in degrees

c = chord $= \sqrt{4(2hr - h^2)}$

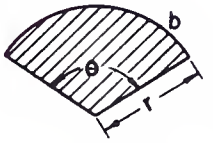
$$\text{Area} = \tfrac{1}{2}[br - c(r - h)] = \pi r^2 \frac{\theta}{360} - \frac{c\,(r - h)}{2}$$

When θ is greater than 180°, then $\frac{c}{2} \times$ difference between r and h is added to the fraction $\frac{\pi r^2 \theta}{360}$

Example. $r = 3$; $\theta = 120°$; $h = 1.5$

$$\text{Area} = 3.1416 \times 3^2 \times \frac{120}{360} - \frac{5.196\ (3 - 1.5)}{2}$$

$= 5.5278$. Ans.



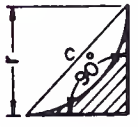
Sector

$$\text{Area} = \frac{br}{2} = \pi r^2 \frac{\theta}{360°}$$

θ = angle in degrees. b = length of arc.

Example. $r = 3$; $\theta = 120°$

$$\text{Area} = 3.1416 \times 3^2 \times \frac{120}{360} = 9.4248. \text{ Ans}$$

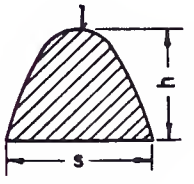


Spandrel

Area $= 0.2146\, r^2 = 0.1073\, c^2$

Example. $r = 3$

Area $= 0.2146 \times 3^2 = 1.9314$. Ans.



Parabola

l = length of curved line = periphery $- s$.

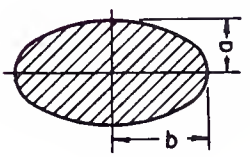
$$l = \frac{s^2}{8h}\left[\sqrt{c(1+c)} + 2.0326 \times \log\left(\sqrt{c} + \sqrt{1+c}\right)\right]$$

in which $c = \left(\frac{4h}{s}\right)^2$

$$\text{Area} = \frac{2}{3}\, sh$$

Example. $s = 3$; $h = 4$

$$\text{Area} = \frac{2}{3} \times 3 \times 4 = 8. \text{ Ans.}$$



Ellipse

Area $= \pi ab = 3.1416\, ab$.

$$\text{Circum.} = \pi (a + b)\, \frac{64 - 3\left(\frac{b-a}{b+a}\right)^4}{64 - 16\left(\frac{b-a}{b+a}\right)^2}$$

[close approximation]

Example. $a = 3$; $b = 4$.

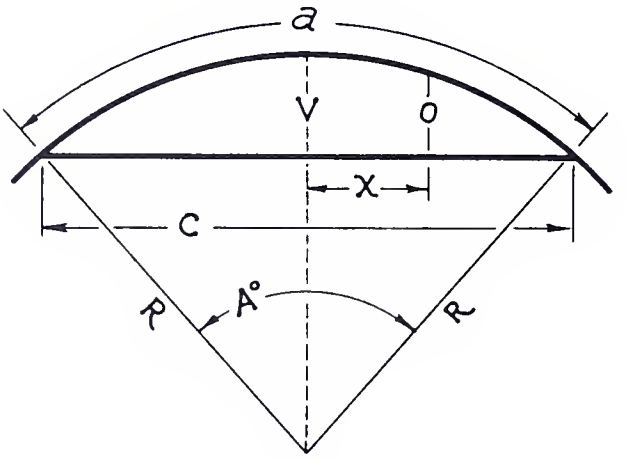
Area $= 3.1416 \times 3 \times 4 = 37.6992$. Ans.

$$\text{Circum.} = 3.1416\ (4 + 3)\, \frac{64 - 3\left(\frac{4-3}{4+3}\right)^4}{64 - 16\left(\frac{4-3}{4+3}\right)^2}$$

$$= 3.1416 \times 7 \times \frac{7529389}{7491120} = 22.13. \text{ Ans.}$$

Figure 18–5

SEGMENT OF A CIRCLE



ANGLE, $A^\circ = \frac{180a}{\pi R} = 57.29578 \frac{a}{R}$ DIAMETER, $D = \frac{4V^2 + C^2}{4V}$

$R = \frac{V^2 + \frac{C^2}{4}}{2V}$ ARC, $a = \frac{\pi R A^\circ}{180} = 0.017453\ R A^\circ$

$O = \sqrt{R^2 - X^2} - (R - V)$ $V = R - \sqrt{R^2 - \frac{C^2}{4}} = \frac{C}{2}$ TAN. $\frac{A^\circ}{4}$

$X = \sqrt{R^2 - (R + O - V)^2}$ $C = 2R \times \text{SINE } \frac{1}{2} A^\circ = 2\sqrt{2VR - V^2}$

LENGTH OF ARC = DEGREES BETWEEN RADII (A°) TIMES LENGTH OF RADIUS (R) TIMES 0.017453.

LENGTH OF ARC = A × R × 0.017453.

LENGTH OF ARC OF 1° = 1 × R × 0.017453.

LENGTH OF ARC OF 1′ = 1 × R × 0.0002909.

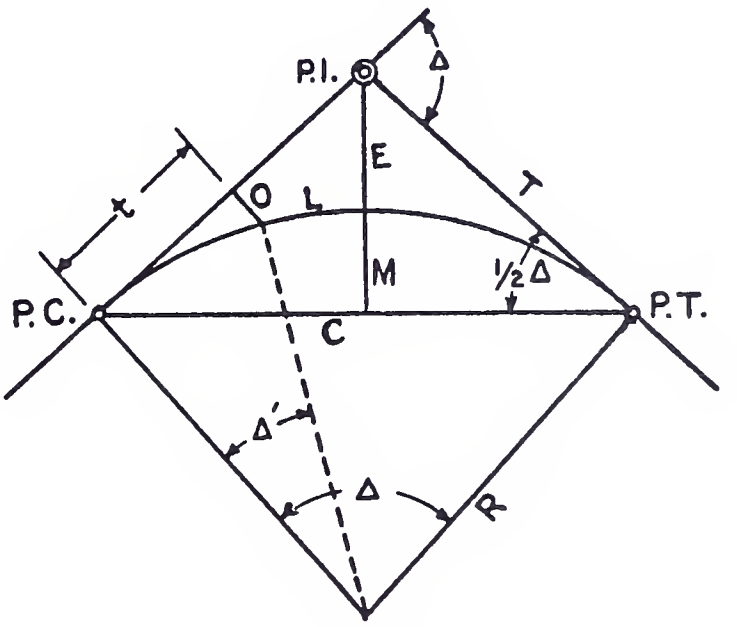
LENGTH OF ARC OF 1″ = 1 × R × 0.0000048.

AREA OF SECTOR = LENGTH OF ARC × $\frac{1}{2}$ R

AREA OF SEGMENT = AREA OF SECTOR − $\frac{C \times (R - V)}{2}$

Figure 18–6

CHORD METHOD
CIRCULAR CURVE DATA



A 1° curve is a curve having a radius such that 1° of central angle subtends a chord of 100′ in length.

D = Degree of Curve

R = Radius

L = Length

T = Tangent

Δ = Central or Deflection Angle

E = External

M = Middle Ordinate

C = Long Chord

O = Tangent Offset

t = Subtangent

$$R = \frac{50}{\text{Sin } \frac{1}{2} D}$$

$$D = \frac{100\ \Delta}{L}$$

$$L = \frac{100\ \Delta}{D}$$

$$\Delta = \frac{DL}{100}$$

$T = R \text{ Tan. } \frac{1}{2} \Delta$

$E = T \text{ Tan. } \frac{1}{4} \Delta$

$E = R \text{ Exsec. } \frac{1}{2} \Delta$

$t = R \text{ Sin } \Delta^1$

$M = R \text{ Versin. } \frac{1}{2} \Delta$

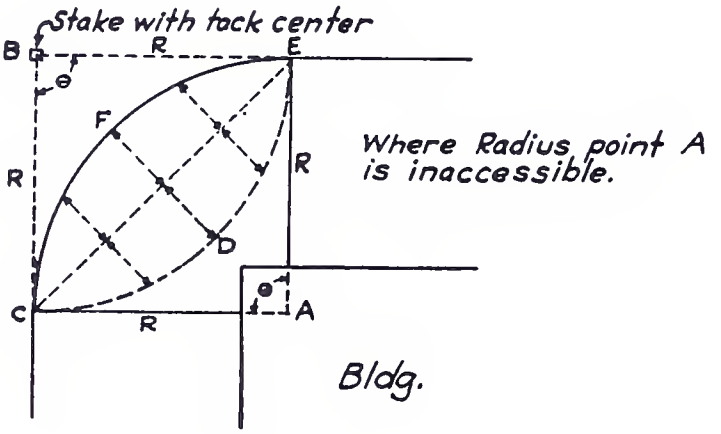
$C = 2R \text{ Sin. } \frac{1}{2} \Delta$

$$O = R - \sqrt{R^2 - t^2}$$

$$O = R - (R \text{ Cos } \Delta^1) = R \text{ Versin. } \Delta^1 = R\ (1 - \text{Cos. } \Delta^1)$$

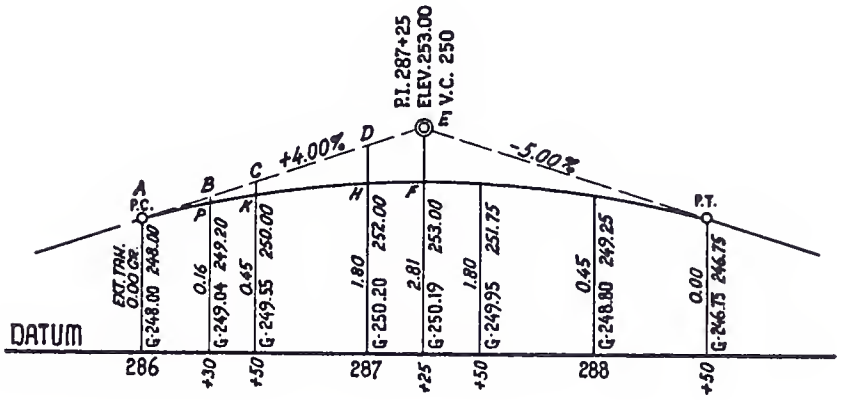
Figure 18–7

METHOD OF STAKING CURB RETURNS



Set stake at B with the same radius and angle θ as at A. Stake curve CDE. Stake Curve CFE by staking offsets from line CE, the same distance as the corresponding offsets from line CE to curve CDE.

DETERMINING CENTER LINE GRADES IN VERTICAL CURVES



The middle external *(E.F.)* is obtained by multiplying the algebraic difference of the grades by the length of curve in 100 foot stations and dividing by 8. (To multiply the algebraic difference of the grades change the sign of one of the grades and add or subtract as the case may be. In the case above change the grade *–5.00* to *+5.00* and add *+4.00* or *9.00* dropping the plus or minus after this operation. When the grades are both plus or minus, change the sign of the larger and subtract, dropping the sign after the operation.)

Taking the example above, compute the grades of the tangent from the P.C. to the P.I. and from the P.I. to the P.T. These computations can be set down either on the drawings as shown above, or on a separate sheet of paper, being careful to set down the results opposite the correct stations.

To obtain the middle external *(E.F.)* we change the sign of *–5.00%* to *+5.00* and add *+4.00* or *9.00*. Multiply this figure by the length of the curve in 100 foot stations or 2.5 and divide by 8, a constant.

$$E.F. = \frac{9 \times 2.5}{8} = 2.8125, \text{ Call } 2.81$$

This external *(2.81)* subtracted from the tangent grade at the P.I. *(253.00)* equals the grade on the curve at F. Therefore center line grade at station 287 + 25 is 253.00 – 2.81 = 250.19.

To find the intermediate externals, B-P, C-K, and D-H, square the distance in feet from the P.C. to the external desired, multiply by the middle external and divide by one-half the length of the curve in feet squared. To find the inter-

mediate externals between the P.I. and the P.T. use the distance from the P.T. to the station in question.

To find the grade at Station 286+30.

$$\text{B-P} = \left(\frac{30}{125}\right)^2 \times 2.81 = 0.16 = \text{external}$$

249.20–0.16 = 249.04, Grade on center line.

To find the grade at Station 286+50.

$$\text{C-K} = \left(\frac{50}{125}\right)^2 \times 2.81 = 0.45 = \text{external}$$

250.00–0.45 = 249.55, Grade on center line.

To find the grade at Station 287+00.

$$\text{D-H} = \left(\frac{100}{125}\right)^2 \times 2.81 = 1.80 = \text{external}$$

252.00–1.80 = 250.20, Grade on center line.

The externals between the P.T. and the P.I. are worked in the same manner, except that the distance from the P.T. to the station wanted is used.

When the curve is concave the externals are added to the tangent grades to obtain the correct center line grade.

Table 18–3

AREA OF CIRCLES AND THEIR CIRCUMFERENCE

Dia.	*Area*	*Cir.*	*Dia.*	*Area*	*Cir.*	*Dia.*	*Area*	*Cir.*	*Dia.*	*Area*	*Cir.*
⅛	0.0123	.3926	10	78.54	31.41	30	706.86	94.24	65	3318.3	204.2
¼	0.0491	.7854	10½	86.59	32.98	31	754.76	97.38	66	3421.2	207.3
⅜	0.1104	1.178	11	95.03	34.55	32	804.24	100.5	67	3525.6	210.4
½	0.1963	1.570	11½	103.86	36.12	33	855.30	103.6	68	3631.6	213.6
⅝	0.3067	1.963	12	113.09	37.69	34	907.92	106.8	69	3739.2	216.7
¾	0.4417	2.356	12½	122.71	39.27	35	962.11	109.9	70	3848.4	219.9
⅞	0.6013	2.748	13	132.78	40.84	36	1017.8	113.0	71	3959.2	223.0
1	0.7854	3.141	13½	143.13	42.41	37	1075.2	116.2	72	4071.5	226.1
1⅛	0.9440	3.534	14	153.93	43.98	38	1134.1	119.3	73	4185.3	229.3
1¼	1.227	3.927	14½	165.13	45.55	39	1194.5	122.5	74	4300.8	232.4
1⅜	1.484	4.319	15	176.71	47.12	40	1256.6	125.6	75	4417.8	235.6
1½	1.767	4.712	15½	188.69	48.69	41	1320.2	128.8	76	4536.4	238.7
1⅝	2.073	5.105	16	201.06	50.26	42	1385.4	131.9	77	4656.0	241.9
1¾	2.405	5.497	16½	213.82	51.83	43	1452.2	135.0	78	4778.3	245.0
1⅞	2.761	5.890	17	226.98	53.40	44	1520.5	138.2	79	4901.6	248.1
2	3.141	6.283	17½	240.52	54.97	45	1590.4	141.3	80	5026.5	251.3
2¼	3.976	7.068	18	254.46	56.54	46	1661.9	144.5	81	5153.0	254.4
2½	4.908	7.854	18½	268.80	58.11	47	1734.9	147.6	82	5281.0	257.6
2¾	5.939	8.639	19	283.52	59.69	48	1809.5	150.7	83	5410.6	260.7
3	7.068	9.424	19½	298.64	61.26	49	1885.7	153.9	84	5541.7	263.8
3¼	8.295	10.21	20	314.16	62.83	50	1963.5	157.0	85	5674.5	267.0
3½	9.621	10.99	20½	330.06	64.40	51	2042.8	160.2	86	5808.8	270.1
3¾	11.044	11.78	21	346.36	65.97	52	2123.7	163.3	87	5944.6	273.3
4	12.566	12.56	21½	363.05	67.54	53	2206.1	166.5	88	6082.1	276.4
4½	15.904	14.13	22	380.13	69.11	54	2290.2	169.6	89	6221.1	279.6
5	19.635	15.70	22½	397.60	70.68	55	2375.8	172.7	90	6361.7	282.7
5½	23.758	17.27	23	415.47	72.25	56	2463.0	175.9	91	6503.8	285.8
6	28.274	18.84	23½	433.73	73.82	57	2551.7	179.0	92	6647.6	289.0
6½	33.183	20.42	24	452.39	75.39	58	2642.0	182.2	93	6792.9	292.1
7	38.484	21.99	24½	471.43	76.96	59	2733.9	185.3	94	6939.7	295.3
7½	44.178	23.56	25	490.87	78.54	60	2827.4	188.4	95	7088.2	298.4
8	50.265	25.13	26	530.93	81.68	61	2922.4	191.6	96	7238.2	301.5
8½	56.745	26.70	27	572.55	84.82	62	3019.0	194.7	97	7389.8	304.7
9	63.617	28.27	28	615.75	87.96	63	3117.2	197.9	98	7542.9	307.8
9½	70.882	29.84	29	660.52	91.10	64	3216.9	201.0	99	7697.7	311.0

Table 18–4

TABLE OF ROUND AND SQUARE BAR WEIGHTS AND AREAS

Round Bars			*Plain Square and Twisted Square Bars*		
Diameter	*Area (Sq. In.)*	*Wt. (lbs. per ft.)*	*Dimension*	*Area (Sq. In.)*	*Wt. (lbs. per ft.)*
1/4"	.0491	.167	1/4"	.0625	.212
5/16"	.0767	.261	5/16"	.0977	.332
3/8"	.1104	.376	3/8"	.1406	.478
7/16"	.1503	.511	7/16"	.1914	.651
1/2"	.1963	.668	1/2"	.2500	.850
9/16"	.2485	.845	9/16"	.3164	1.076
5/8"	.3068	1.043	5/8"	.3906	1.328
11/16"	.3712	1,262	11/16"	.4727	1.607
3/4"	.4418	1.502	3/4"	.5625	1.913
13/16"	.5185	1.763	13/16"	.6602	2.245
7/8"	.6013	2.044	7/8"	.7656	2.603
15/16"	.6903	2.347	15/16"	.8789	2.988
1 "	.7854	2.670	1 "	1.0000	3.400
1 1/8"	.9940	3.380	1 1/8"	1.2656	4.303
1 1/4"	1.2272	4.172	1 1/4"	1.5625	5.313
1 3/8"	1.4849	5.049	1 3/8"	1.8906	6.428
1 1/2"	1.7671	6.008	1 1/2"	2.2500	7.650

Table 18–5

TABLE CONVERTING INCHES AND FRACTIONS OF INCHES INTO DECIMALS OF A FOOT

Fraction of Ins.	*0"*	*1"*	*2"*	*3"*	*4"*	*5"*	*6"*	*7"*	*8"*	*9"*	*10"*	*11"*
0	.0000	.0833	.1667	.2500	.3333	.4167	.5000	.5833	.6667	.7500	.8333	.9167
1/16	.0052	.0885	.1719	.2552	.3385	.4219	.5082	.5885	.6719	.7552	.8385	.9219
1/8	.0104	.0938	.1771	.2604	.3438	.4271	.5104	.5938	.6771	.7604	.8438	.9271
3/16	.0156	.0990	.1823	.2656	.3490	.4323	.5156	.5900	.6823	.7656	.8490	.9323
1/4	.0208	.1042	.1875	.2708	.3542	.4375	.5208	.6042	.6875	.7708	.8542	.9375
5/16	.0260	.1094	.1927	.2760	.3594	.4427	.5260	.6094	.6927	.7760	.8594	.9427
3/8	.0313	.1146	.1979	.2813	.3646	.4479	.5313	.6146	.6979	.7813	.8646	.9479
7/16	.0365	.1198	.2031	.2865	.3698	.4531	.5365	.6198	.7031	.7865	.8698	.9531
1/2	.0417	.1250	.2083	.2917	.3750	.4583	.5417	.6250	.7083	.7917	.8750	.9583
9/16	.0469	.1302	.2135	.2969	.3802	.4635	.5469	.6302	.7135	.7969	.8802	.9635
5/8	.0521	.1354	.2188	.3021	.3854	.4688	.5521	.6354	.7188	.8021	.8854	.9688
11/16	.0573	.1406	.2240	.3073	.3906	.4740	.5573	.6406	.7240	.8073	.8906	.9740
3/4	.0623	.1458	.2292	.3125	.3858	.4792	.5625	.6458	.7292	.8125	.8958	.9792
13/16	.0677	.1510	.2344	.3177	.4010	.4844	.5677	.6510	.7344	.8177	.9010	.9844
7/8	.0729	.1563	.2396	.3229	.4063	.4896	.5729	.6563	.7396	.8229	.9063	.9896
15/16	.0718	.1615	.2448	.3281	.4115	.4948	.5781	.6615	.7448	.8281	.9115	.9948
1												1.0000

Table 18–6

TABLE OF OUNCES AND HALF OUNCES REDUCED TO DECIMALS OF A POUND

1	.062	8½	.531
1½	.094	9	562
2	.125	9½	.594
2½	.156	10	.625
3	.187	10½	.656
3½	.219	11	.687
4	.250	11½	.719
4½	.281	12	.750
5	.312	12½	.781
5½	.344	13	.812
6	.375	13½	.844
6½	.406	14	.875
7	.437	14½	.906
7½	.469	15	.935
8	.500	15½	.969

Table 18–7

DECIMAL OF AN INCH AND A FOOT

Fraction of Inch or Foot		*Inch Equivalents to Foot Fractions*	*Fraction of Inch or Foot*		*Inch Equivalents to Foot Fractions*	*Fraction of Inch or Foot*		*Inch Equivalents to Foot Fractions*	*Fraction of Inch or Foot*		*Inch Equivalents to Foot Fractions*
	.0052	1/16		.2552	3 1/16		.5052	6 1/16		.7552	9 1/16
	.0104	1/8		.2604	3 1/8		.5104	6 1/8		.7604	9 1/8
1/64	.015625	3/16	17/64	.265625	3 3/16	33/64	.515625	6 3/16	49/64	.765625	9 3/16
	.0208	1/4		.2708	3 1/4		.5208	6 1/4		.7708	9 1/4
	.0260	5/16		.2760	3 5/16		.5260	6 5/16		.7760	9 5/16
1/32	.03125	3/8	9/32	.28125	3 3/8	17/32	.53125	6 3/8	25/32	.78125	9 3/8
	.0365	7/16		.2865	3 7/16		.5365	6 7/16		.7865	9 7/16
	.0417	1/2		.2917	3 1/2		.5417	6 1/2		.7917	9 1/2
3/64	.046875	9/16	19/64	.296875	3 9/16	35/64	.546875	6 9/16	51/64	.796875	9 9/16
	.0521	5/8		.3021	3 5/8		.5521	6 5/8		.8021	9 5/8
	.0573	11/16		.3073	3 11/16		.5573	6 11/16		.8073	9 11/16
1/16	.0625	3/4	5/16	.3125	3 3/4	9/16	.5625	6 3/4	13/16	.8125	9 3/4
	.0677	13/16		.3177	3 13/16		.5677	6 13/16		.8177	9 13/16
	.0729	7/8		.3229	3 7/8		.5729	6 7/8		.8229	9 7/8
5/64	.078125	15/16	21/64	.328125	3 15/16	37/64	.578125	6 15/16	53/64	.828125	9 15/16
	.0833	1		.3333	4		.5883	7		.8333	10
	.0885	1 1/16		.3385	4 1/16		.5885	7 1/16		.8385	10 1/16
3/32	.09375	1 1/8	11/32	.34375	4 1/8	19/32	.59375	7 1/8	27/32	.84375	10 1/8
	.0990	1 3/16		.3490	4 3/16		.5990	7 3/16		.8490	10 3/16
	.1042	1 1/4		.3542	4 1/4		.6042	7 1/4		.8542	10 1/4
7/64	.109375	1 5/16	23/64	.359375	4 5/16	39/64	.609375	7 5/16	55/64	.859375	10 5/16
	.1146	1 3/8		.3646	4 3/8		.6146	7 3/8		.8646	10 3/8
	.1198	1 7/16		.3698	4 7/16		.6198	7 7/16		.8698	10 7/16
1/8	.1250	1 1/2	3/8	.3750	4 1/2	5/8	.6250	7 1/2	7/8	.8750	10 1/2
	.1302	1 9/16		.3802	4 9/16		.6302	7 9/16		.8802	10 9/16
	.1354	1 5/8		.3854	4 5/8		.6354	7 5/8		.8854	10 5/8
9/64	.140625	1 11/16	25/64	.390625	4 11/16	41/64	.640625	7 11/16	57/64	.890625	10 11/16
	.1458	1 3/4		.3958	4 3/4		.6458	7 3/4		.8958	10 3/4
	.1510	1 13/16		.4010	4 13/16		.6510	7 13/16		.9010	10 13/16

Table 18–7 (Cont'd.)

DECIMAL OF AN INCH AND A FOOT

Fraction of Inch or Foot		Inch Equivalents to Foot Fractions	Fraction of Inch or Foot		Inch Equivalents to Foot Fractions	Fraction of Inch or Foot		Inch Equivalents to Foot Fractions	Fraction of Inch or Foot		Inch Equivalents to Foot Fractions
5/32	.15625	1 7/8	13/32	.40625	4 7/8	21/32	.65625	7 7/8	29/32	.90625	10 7/8
	.1615	1 15/16		.4115	4 15/16		.6615	7 15/16		.9115	10 15/16
	.1667	2		.4167	5		.6667	8		.9167	11
11/64	.171875	2 1/16	27/64	.421875	5 1/16	43/64	.671875	8 1/16	59/64	.921875	11 1/16
	.1771	2 1/8		.4271	5 1/8		.6771	8 1/8		.9271	11 1/8
	.1823	2 3/16		.4323	5 3/16		.6823	8 3/16		.9323	11 3/16
3/16	.1875	2 1/4	7/16	.4375	5 1/4	11/16	.6875	8 1/4	15/16	.9375	11 1/4
	.1927	2 5/16		.4427	5 5/16		.6927	8 5/16		.9427	11 5/16
	.1979	2 3/8		.4479	5 3/8		.6979	8 3/8		.9479	11 3/8
13/64	.203125	2 7/16	29/64	.453125	5 7/16	45/64	.703125	8 7/16	61/64	.953125	11 7/16
	.2083	2 1/2		.4583	5 1/2		.7083	8 1/2		.9583	11 1/2
	.2135	2 9/16		.4635	5 9/16		.7135	8 9/16		.9635	11 9/16
7/32	.21875	2 5/8	15/32	.46875	5 5/8	23/32	.71875	8 5/8	31/32	.96875	11 5/8
	.2240	2 11/16		.4740	5 11/16		.7240	8 11/16		.9740	11 11/16
	.2292	2 3/4		.4792	5 3/4		.7292	8 3/4		.9792	11 3/4
15/64	.234375	2 13/16	37/64	.484375	5 13/16	47/64	.734375	8 13/16	63/64	.984375	11 13/16
	.2396	2 7/8		.4896	5 7/8		.7396	8 7/8		.9896	11 7/8
	.2448	2 15/16		.4948	5 15/16		.7448	8 15/16		.9948	11 15/16
1/4	.2500	3	1/2	.5000	6	3/4	.7500	9	1	1.0000	12

Table 18–8

MILES AND TENTHS REDUCED TO FEET

Miles	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	0.1
Feet	5280	5808	6336	6864	7392	7920	8448	8976	9504	10032	528
Miles	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	0.2
Feet	10560	11088	11616	12144	12672	13200	13728	14256	14784	15312	1056
Miles	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	0.3
Feet	15840	16368	16896	17424	17952	18480	19008	19536	20064	20592	1584
Miles	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	0.4
Feet	21120	21648	22176	22704	23232	23760	24288	24816	25344	25872	2112
Miles	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.9	0.5
Feet	26400	26928	27456	27984	28512	29040	29568	30096	30624	31152	2644
Miles	6.0	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9	0.6
Feet	31680	32208	32736	33264	33792	34320	34848	35376	35904	36432	3168
Miles	7.0	7.1	7.2	7.3	7.4	7.5	7.6	7.7	7.8	7.9	0.7
Feet	36960	37488	38016	38544	39072	39600	40128	40656	41184	41712	3696
Miles	8.0	8.1	8.2	8.3	8.4	8.5	8.6	8.7	8.8	8.9	0.8
Feet	42240	42768	43296	43824	44352	44880	45408	45936	46464	46992	4224
Miles	9.0	9.1	9.2	9.3	9.4	9.5	9.6	9.7	9.8	9.9	0.9
Feet	47520	48048	48576	49104	49632	50160	50688	51216	51744	52272	4752

Table 18–9

AREAS OF PAVEMENT SURFACES

Width in Feet	*Square Feet Per Mile*	*Square Yards Per Mile*	*Square Yards Per Lin. Ft.*
1	5,280	587	0.1111
8	42,240	4,693	0.8888
9	47,520	5,280	1.0000
10	52,800	5,867	1.1111
11	58,080	6,453	1.2222
12	63,360	7,040	1.3333
15	79,200	8,800	1.6667
16	84,480	9,387	1.7778
18	95,040	10,560	2.0000
20	105,600	11,733	2.2222
22	116,160	12,906	2.4444
24	126,720	14,080	2.6667
26	137,280	15,253	2.8888
28	147,840	16,426	3.1110
30	158,400	17,600	3.3333
32	168,960	18,773	3.5555
36	190,080	21,120	4.0000
40	211,200	23,467	4.4444
50	264,000	29,333	5.5556

Table 18–10

TABLE OF THERMOMETRIC EQUIVALENTS
Centigrade and Fahrenheit

C°	*F°*	*C°*	*F°*	*C°*	*F°*	*C°*	*F°*
0	32	51	123.8	103	217.4	155	311
1	33.8	52	125.6	104	219.2	156	312.8
2	35.6	53	127.4	105	221	157	314.6
3	37.4	54	129.2	106	222.8	158	316.4
4	39.2	55	131	107	224.6	159	318.2
5	41	56	132.8	108	226.4	160	320
6	42.8	57	134.6	109	228.2	161	321.8
7	44.6	58	136.4	110	230	162	323.6
8	46.4	59	138.2	111	231.8	163	325.4
9	48.2	60	140	112	233.6	164	327.2
10	50	61	141.8	113	235.4	165	329
11	51.8	62	143.6	114	237.2	166	330.8
12	53.6	63	145.4	115	239	167	332.6
13	55.4	64	147.2	116	240.8	168	334.4
14	57.2	65	149	117	242.6	169	336.2
15	59	66	150.8	118	244.4	170	338
15.5	60	67	152.6	119	246.2	171	339.8
16	60.8	68	154.4	120	248	172	341.6
17	62.6	69	156.2	121	249.8	173	343.4
18	64.4	70	158	122	251.6	174	345.2
19	66.2	71	159.8	123	253.4	175	347
20	68	72	161.6	124	255.2	176	348.8
21	69.8	73	163.4	125	257	177	350.6
22	71.6	74	165.2	126	258.8	178	352.4
23	73.4	75	167	127	260.6	179	354.2
24	75.2	76	168.8	128	262.4	180	356.2
25	77	77	170.6	129	264.2	181	357.8
26	78.8	78	172.4	130	266	182	359.6
27	80.6	79	174.2	131	267.8	183	361.4
28	82.4	80	176	132	269.6	184	363.2
29	84.2	81	177.8	133	271.4	185	365
30	86	82	179.6	134	273.2	186	366.8
31	87.8	83	181.4	135	275	187	368.6
32	89.6	84	183.2	136	276.8	188	370.4
33	91.4	85	185	137	278.6	189	372.2
34	93.2	86	186.8	138	280.4	190	374
35	95	87	188.6	139	282.2	191	375.8
36	96.8	88	190.4	140	284	192	377.6
37	98.6	89	192.2	141	285.8	193	379.4

Table 18–10 (Cont'd.)

TABLE OF THERMOMETRIC EQUIVALENTS—Cont'd
Centigrade and Fahrenheit

C°	F°	C°	F°	C°	F°	C°	F°
38	100.4	90	194	142	287.6	194	381.2
39	102.2	91	195.8	143	289.4	195	383
40	104	92	197.6	144	291.2	196	384.8
41	105.8	93	199.4	145	293	197	386.6
42	107.6	94	201.2	146	294.8	198	388.4
43	109.4	95	203	147	296.6	199	390.2
44	111.2	96	204.8	148	298.4	200	392
45	113	97	206.6	149	300.2	201	393.8
46	114.8	98	208.4	150	302	202	395.6
47	116.6	99	210.2	151	303.8	203	397.4
48	118.4	100	212	152	305.6	204	399.2
49	120.2	101	213.8	153	307.4	204.4	400
50	122	102	215.6	154	309.2	205	401

Table 18–11

BOARD MEASURE

A board foot is a foot long and has an end area of twelve (12) square inches. The table below gives the contents in board feet per each piece of lumber.

Size in Inches	*Length of Lumber in Feet*							
	10	*12*	*14*	*16*	*18*	*20*	*22*	*24*
1 x 2	1⅔	2	2⅓	2⅔	3	3⅓	3⅔	4
1 x 3	2½	3	3½	4	4½	5	5½	6
1 x 4	3⅓	4	4⅔	5⅓	6	6⅔	7⅓	8
1 x 5	4⅙	5	5⅚	6⅔	7½	8⅓	9⅙	10
1 x 6	5	6	7	8	9	10	11	12
1 x 7	5⅚	7	8⅙	9⅓	10½	11⅔	12⅚	14
1 x 8	6⅔	8	9⅓	10⅔	12	13⅓	14⅔	16
1 x 10	8⅓	10	11⅔	13⅓	15	16⅔	18⅓	20
1 x 12	10	12	14	16	18	20	22	24
1 x 14	11⅔	14	16⅓	18⅔	21	23⅓	25⅔	28
1 x 16	13⅓	16	18⅔	21⅓	24	26⅔	29⅓	32
1 x 18	15	18	21	24	27	30	33	36
1 x 20	16⅔	20	23⅓	26⅔	30	33⅓	36⅔	40
1¼ x 4	4⅙	5	5⅚	6⅔	7½	8⅓	9⅙	10
1¼ x 6	6¼	7½	8¾	10	11¼	12½	13¾	15
1¼ x 8	8⅓	10	11⅔	13⅓	15	16⅔	18⅓	20
1¼ x 10	10 5/12	12½	14 7/12	16⅔	18¾	20⅝	22 11/12	25
1¼ x 12	12½	15	17½	20	22½	25	27½	30
1½ x 4	5	6	7	8	9	10	11	12
1½ x 6	7½	9	10½	12	13½	15	16½	18
1½ x 8	10	12	14	16	18	20	22	24
1½ x 10	12½	15	17½	20	22½	25	27½	30
1½ x 12	15	18	21	24	27	30	33	36
10 x 10	83⅓	100	116⅔	133⅓	150	166⅔	183⅓	200
10 x 12	100	120	140	160	180	200	220	240
10 x 14	116⅔	140	163⅓	186⅔	210	233⅓	256⅔	280
10 x 16	133⅓	160	186⅔	213⅓	240	266⅔	293⅓	320
12 x 12	120	144	168	192	216	240	264	288
12 x 14	140	168	196	224	252	280	308	336
12 x 16	160	192	224	256	288	320	352	384
14 x 14	163⅓	196	227⅔	261⅓	294	326⅔	359⅓	392
14 x 16	186⅔	224	261⅓	298⅔	336	373⅓	410⅔	448
2 x 4	6⅔	8	9⅓	10⅔	12	13⅓	14⅔	16
2 x 6	10	12	14	16	18	20	22	24
2 x 8	13⅓	16	18⅔	21⅓	24	26⅔	29⅓	32
2 x 10	16⅔	20	23⅓	26⅔	30	33⅓	36⅔	40
2 x 12	20	24	28	32	36	40	44	48
2 x 14	23⅓	28	37⅓	37⅓	42	46⅔	51⅓	56
2 x 16	26⅔	32	32⅔	42⅔	48	53⅓	58⅔	64

Table 18–11 (Cont'd.)

BOARD MEASURE

Size in Inches	*Length of Lumber in Feet*							
	10	*12*	*14*	*16*	*18*	*20*	*22*	*24*
2½ x 12	25	30	35	40	45	50	55	60
2½ x 14	29⅙	35	40⅚	46⅔	52½	58⅓	64⅙	70
2½ x 16	33⅓	40	46⅔	53⅓	60	66⅔	73⅓	80
3 x 6	15	18	21	24	27	30	33	36
3 x 8	20	24	28	32	36	40	44	48
3 x 10	25	30	35	40	45	50	55	60
3 x 12	30	36	42	48	54	60	66	72
3 x 14	35	42	49	56	63	70	77	84
3 x 16	40	48	56	64	72	80	88	96
4 x 4	13⅓	16	18⅔	21⅓	24	26⅔	29⅓	32
4 x 6	20	24	28	32	36	40	44	48
4 x 8	26⅔	32	37⅓	42⅔	48	53⅓	58⅔	64
4 x 10	33⅓	40	46⅔	53⅓	60	66⅔	73⅓	80
4 x 12	40	48	56	64	72	80	88	96
4 x 14	46⅔	56	65⅓	74⅔	84	93⅓	102⅔	112
6 x 6	30	36	42	48	54	60	66	72
6 x 8	40	48	56	64	72	80	88	96
6 x 10	50	60	70	80	90	100	110	120
6 x 12	60	72	84	96	108	120	132	144
6 x 14	70	84	98	112	126	140	154	168
6 x 16	80	96	112	128	144	160	176	192
8 x 8	53⅓	64	74⅔	85⅓	96	106⅔	117⅓	128
8 x 10	66⅔	80	93⅓	106⅔	120	133⅓	146⅔	160
8 x 12	80	96	112	128	144	160	176	192
8 x 14	93⅓	112	130⅔	149⅓	168	186⅔	205⅓	224

Table 18–12

WIRE GAUGE
COLD-DRAWN STEEL WIRE FOR CONCRETE REINFORCEMENT
(A.A.S.H.O. Designation: M-32)
SIZE

Gauge Number	*Equivalent Diameter, In.*
0000000	0.4900
000000	0.4615
00000	0.4305
0000	0.3938
000	0.3625
00	0.3310
0	0.3065
1	0.2830
2	0.2625
3	0.2437
4	0.2253
5	0.2070
6	0.1920
7	0.1770
8	0.1620
9	0.1483
10	0.1350
11	0.1205
12	0.1055
13	0.0915
14	0.0800

Figure 18–8

METHOD OF MEASURING INTERSECTIONS, EXCAVATION FOR DITCHES AND DRIVES

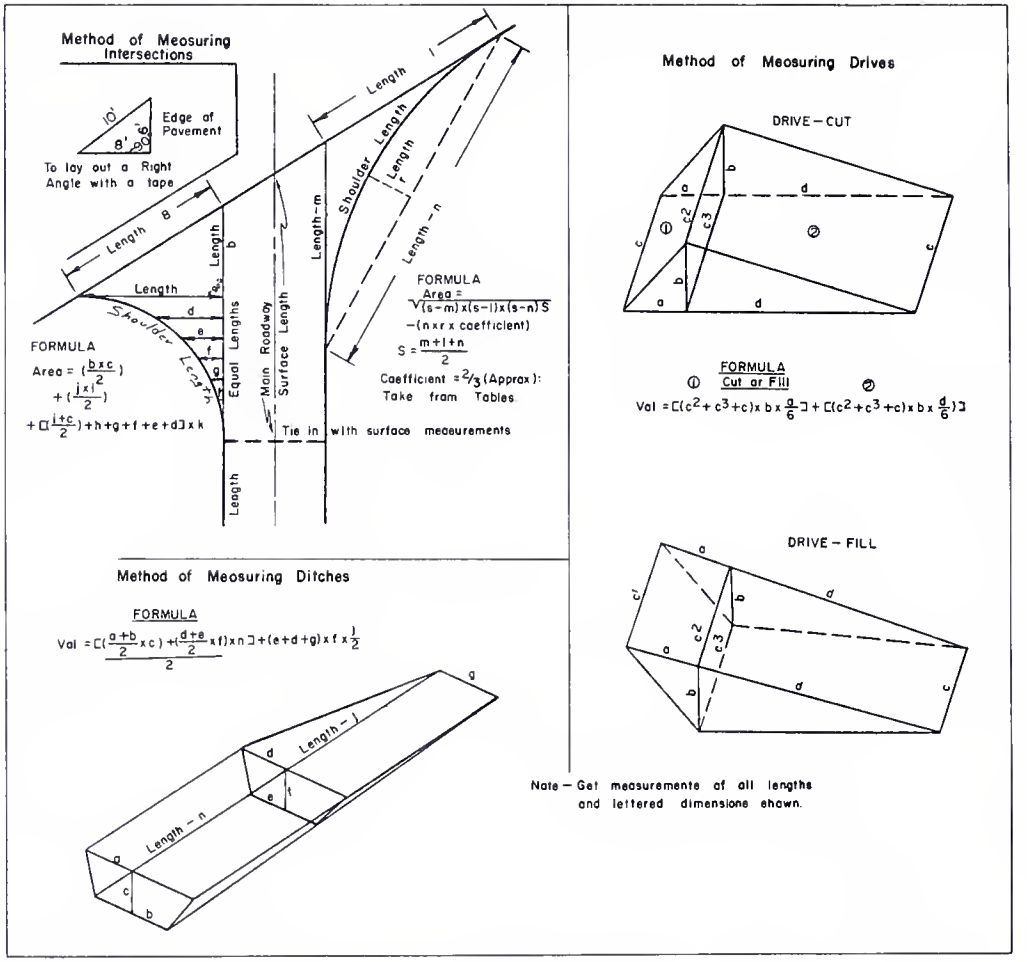
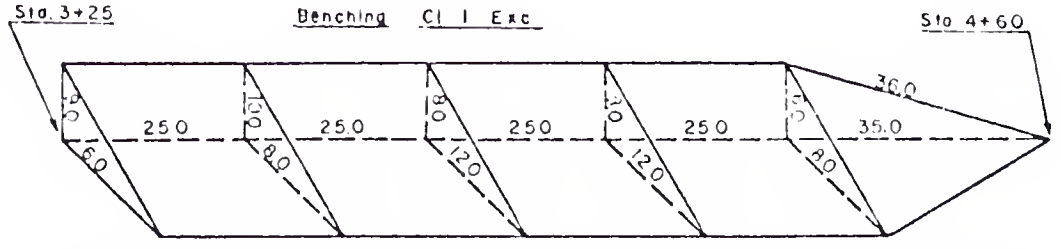

Method of Meosuring Intersections
10'
8'
6'
Edge of Pavement
To lay out a Right Angle with a tape
Length B
Length
Length
Shoulder Length
Length
Length - m
Length - n
Shoulder Length
Equal Lengths
Main Roadway Surface Length
Length
FORMULA
Area = (b x c / 2) + (j x l / 2) + [(i + c / 2) + h + g + f + e + d] x k
FORMULA
Area = √((s-m) x (s-l) x (s-n) S) - (n x r x coefficient)
S = (m + l + n) / 2
Coefficient = 2/3 (Approx): Take from Tables
Tie in with surface measurements
Method of Meosuring Drives
DRIVE – CUT
FORMULA
① Cut or Fill ②
Vol = [(c2 + c3 + c) x b x a/6] + [(c2 + c3 + c) x b x d/6]
DRIVE – FILL
Method of Meosuring Ditches
FORMULA
Vol = [((a+b)/2 x c) + ((d+e)/2 x f) x n] + (e + d + g) x f x 1/2
Length – j
Length – n
Note – Get measurements of all lengths and lettered dimensions shown.

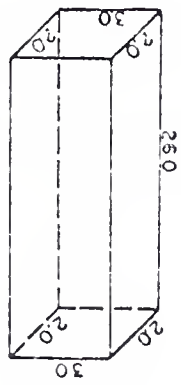
Figure 18–9

METHOD OF MEASURING PIPE REMOVAL, BENCHING



$$\frac{\left(\frac{9+10}{2}\times\frac{6+8}{2}\times 25\right)+\left(\frac{10+8}{2}\times\frac{8+12}{2}\times 25\right)+\left(8\times 12\times 25\right)+\left(\frac{8+6}{2}\times\frac{12+8}{2}\times 25\right)}{2}+\frac{\left(\frac{6\times 8}{2}\times 35\right)}{3}=\frac{8343}{27}=309\ \text{C.Y.}$$

Pipe Removal Sta 4+35



$2\times 3\times 26.0=\frac{156}{27}=6$ C.Y. Cl. 2 Exc.

Rock Subgrade Sta. 4+53 – 6+79

$0.5\times\frac{15+20}{12}\times 12=105.0$

$0.5\times\frac{10+15}{2}\times 14=87.5$

Cl. 1 Exc. 192.5 ÷ 27 = 7.4

Unsuitable Material

Sta 3+60 – 3+82 Cl. 1 Exc.

$1.5\times 10\times 20=300.0$

$1.5\times 12\times\frac{15+22}{2}=333.0$

$\frac{300.0+333.0}{27}=23$ C.Y.

Figure 18–10

METHOD OF MEASURING AND RECORDING, GUARD FENCE, PIPE, TILE, UNDERDRAIN, ETC.

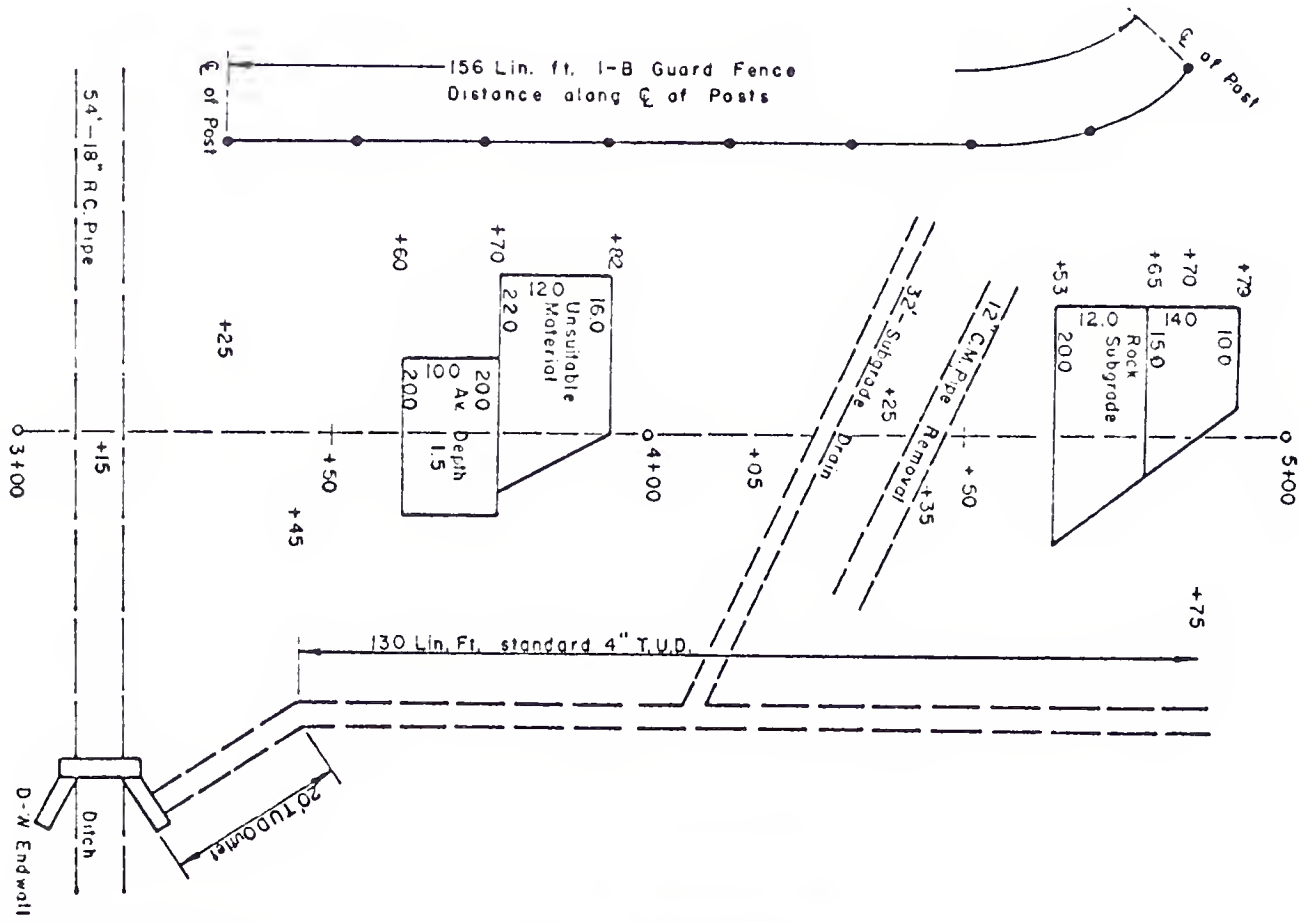


Table 18–13

COMMONLY USED CONVERSION FACTORS

Multiply	*By*	*To Obtain*
Acres	43,560	Square feet
Acres	1.562×10^{-3}	Square miles
Acre-feet	43,560	Cubic feet
Amperes per sq. cm.	6.452	Amperes per sq. in.
Amperes per sq. in.	0.1550	Amperes per sq. cm.
Ampere-turns	1.257	Gilberts
Ampere-turns per cm.	2.540	Ampere-turns per in.
Ampere-turns per in.	0.3937	Ampere-turns per cm.
Atmospheres	76.0	Cm. of mercury
Atmospheres	29.92	Inches of mercury
Atmospheres	33.90	Feet of water
Atmospheres	14.70	Pounds per sq. in.
British thermal units	0.2520	Kilogram-calories
British thermal units	777.5	Foot-pounds
British thermal units	3.927×10^{-4}	Horsepower-hours
British thermal units	2.928×10^{-4}	Kilowatt-hours
Bushels	1.244	Cubic feet
Centimeters	0.3937	Inches
Circular mils	5.067×10^{-6}	Square centimeters
Circular mils	7.853×10^{-7}	Square inches
Circular mils	0.7854	Square mils
Cords	128	Cubic feet
Cubic centimeters	6.102×10^{-2}	Cubic inches
Cubic feet	0.02832	Cubic meters
Cubic feet	7.481	Gallons
Cubic feet	28.32	Liters
Cubic inches	16.39	Cubic centimeters
Cubic meters	35.31	Cubic feet
Cubic meters	1.308	Cubic yards
Cubic yards	0.7646	Cubic meters
Degrees (angle)	0.01745	Radians
Dynes	2.248×10^{-6}	Pounds
Ergs	7.376×10^{-8}	Foot-pounds
Farads	10^{6}	Microfarads
Fathoms	6	Feet
Feet	30.48	Centimeters
Feet of water	0.8826	Inches of mercury
Feet of water	304.8	Kg per square meter
Feet of water	62.43	Pounds per square ft.
Feet of water	0.4335	Pounds per square in.
Foot-pounds	1.286×10^{-3}	British thermal units
Foot-pounds	5.050^{-7}	Horsepower-hours
Foot-pounds	0.1383	Kilogram-meters
Foot-pounds	3.766×10^{-7}	Kilowatt-hours
Gallons	0.1337	Cubic feet
Gallons	231	Cubic inches
Gallons	3.785×10^{-3}	Cubic meters
Gallons	3.785	Liters
Gallons per minute	2.228×10^{-3}	Cubic feet per sec.
Gausses	6.452	Lines per square in.
Gilberts	0.7958	Ampere-turns
Henries	10^{3}	Millihenries
Horsepower	42.44	Btu. per min.
Horsepower	33,000	Foot-pounds per min.
Horsepower	1.014	Horsepower (metric)
Horsepower	10.70	Kg calories per min.
Horsepower	0.7457	Kilowatts
Hoserpower (boiler)	33,520	Btu. per hr.
Horsepower-hours	2.547	British thermal units
Horsepower-hours	1.98×10^{6}	Foot-pounds

Table 18–13 (Con'td.)

COMMONLY USED CONVERSION FACTORS—Cont'd

Multiply	*By*	*To Obtain*
Inches	2.540	Centimeters
Inches of mercury	1.133	Feet of water
Inches of mercury	70.73	Pounds per square ft.
Inches of mercury	0.4912	Pounds per square in.
Inches of water	25.40	Kg per square meter
Inches of water	0.5781	Ounces per square in.
Inches of water	5.204	Pounds per square ft.
Joules	9.486×10^{-4}	British thermal units
Joules	0.7376	Foot-pounds
Kilograms	2.205	Pounds
Kilogram-calories	3.968	British thermal units
Kilogram-meters	7.233	Foot-pounds
Kg per square meter	3.281×10^{-3}	Feet of water
Kg per square meter	0.2048	Pounds per square feet
Kg per square meter	1.422×10^{-3}	Pounds per square inch
Kilolines	10^{3}	Maxwells
Kilometers	3,281	Feet
Kilometers	0.6214	Miles
Kilowatts	56.92	Btu. per min.
Kilowatts	737.6	Foot-pounds per sec.
Kilowatts	1.341	Horsepower
Kilowatt-hours	3,415	British thermal units
Kilowatt-hours	2.655×10^{6}	Foot-pounds
Knots	1.152	Miles
Liters	0.03531	Cubic feet
Liters	61.02	Cubic inches
Liters	0.2642	Gallons
LogeN or ln N	0.4343	$Log_{10}N$ or ln N
$Log_{10}N$	2.303	LogeN or ln N
Lumens per square ft.	1	Foot-candles
Maxwells	10^{-3}	Kilolines
Megalines	10^{6}	Maxwells
Megohms	10^{6}	Ohms
Meters	3.281	Feet
Meters	39.37	Inches
Meter-kilograms	7.233	Pound-feet
Microfarads	10^{-6}	Farads
Microhms	10^{-6}	Ohms
Microhms per cm cube	0.3937	Microhms per inch cube
Microhms per cm cube	6.015	Ohms per mil foot
Miles	5,280	Feet
Miles	1.609	Kilometers
Miner's inches	1.5	Cubic feet per min.
Ohms	10^{-6}	Megohms
Ohms	10^{6}	Microhms
Ohms per mil foot	0.1662	Microhms per cm. cube
Ohms per mil foot	0.06524	Microhms per inch cube
Poundals	0.03108	Pounds
Pounds	32.17	Poundals
Pounds-feet	0.1383	Meter-kilograms
Pounds of water	0.01602	Cubic feet
Pounds of water	0.1198	Gallons
Pounds per cubic foot	16.02	Kg per cubic meter
Pounds per cubic foot	5.787×10^{-4}	Pounds per cubic cm.
Pounds per cubic inch	27.68	Grams per cubic cm.
Pounds per cubic inch	2.768×10^{4}	Kg per cubic meter
Pounds per cubic inch	1,728	Pounds per cubic foot
Pounds per square foot	0.01602	Feet of water
Pounds per square foot	4.882	Kg per square meter
Pounds per square foot	6.944×10^{-3}	Pounds per square in.
Pounds per square inch	2.307	Feet of water
Pounds per square inch	2.036	Inches of mercury
Pounds per square inch	703.1	Kg per square meter

Table 18–13 (Con'td.)

COMMONLY USED CONVERSION FACTORS—Cont'd

Multiply	*By*	*To Obtain*
Radians	57.30	Degrees
Square centimenters	1.973×10^{5}	Circular mils
Square feet	2.296×10^{-5}	Acres
Square feet	0.09290	Square meters
Square inches	1.273×10^{6}	Circular mils
Square inches	6.452	Square centimeters
Square kilometers	0.3861	Square miles
Square meters	10.76	Square feet
Square miles	640	Acres
Square miles	2.590	Square kilometers
Square millimeters	1.973×10^{3}	Circular mils
Square mils	1,273	Circular mils
Temperature (C+273)	1	Absolute temp (C)
Temperature (C+17.8)	1.8	Temp (F)
Temperature (F+460)	1	Absolute temp (F)
Temperature (F—32)	5/9	Temp (C)
Tons (long)	2,240	Pounds
Tons (metric)	2,205	Pounds
Tons (short)	2,000	Pounds

Example—
" $\times 10^{-4}$", Shift decimal point four places to left.
" $\times 10^{4}$ ", Shift decimal point four places to right.

CHAPTER NINETEEN

ELECTRONIC DATA PROCESSING
TRAVERSE COMPUTATIONS—PROGRAM 28.0.011

19–1 The Bureau of Electronic Data Processing currently has optional Programs which will perform the following design tasks:

A. Computation of coordinates for open or closed traverse with up to 130 or more courses. Required input information consists of:
   (1) Starting coordinates. This information may be assumed.
   (2) Angular data in the form of Deflection Angles, Bearings, or Azimuth (or any mixture of these).
   (3) Course lengths which may be given as distances or by P. I. Stations in the case of fly lines without horizontal curvature.

B. Computation of Bearings, Azimuths and Course lengths utilizing P. I. Coordinates from any source such as scaling from a gridded map or from other computation results. P. I.'s may be identified by station or number.

C. Traverse adjustment by any one or all of three methods:
Transit rule; Compass Rule; and Rappleye's Method of Least Squares.
   (1) Traverse may be open or closed.
   (2) Required input data consists of:
      (a) Coordinates from previous calculations.
      (b) Closing coordinates: for a closed traverse these are, of course, the beginning coordinates; and for an open traverse they are the known coordinates of the final tie-in point.
      (c) Unless, otherwise specified, all three adjustment methods will be accomplished and furnished to user.
   (3) Output will consist of adjusted coordinates for each P. I., adjusted course length, adjusted Bearings, adjusted Azimuths, and adjusted intersection angles. The radial error will be shown in feet along with the total distance in the traverse and the accuracy ratio. (See Figure 19–4)

D. Area computation for closed figures. The area of any closed adjusted traverse can be computed by the Double Meridian Distance method and will be shown in square feet and in acres. (See Fig. 19–2A)

19–2 General Notes

(a) Input distances or stations are to hundredths of a foot.
(b) Input and Output angles are to the nearest second.
(c) Coordinates are to the hundredths of a foot.
(d) Input data can generally be processed and mailed within one day after receipt of data depending on current work load.

(e) Work already accomplished may be checked electronically. A copy of your coordinate computation form being sufficient input.

(f) Traverse Input Sheets are used for Input listing except for operations described in paragraph 19–1B above where special forms, available from the Bureau, must be used. Samples of regular forms are enclosed. (See Figures 19–1, 19–2, 19–2A). If any doubt exists, a sketch of the traverse with all pertinent information shown will be sufficient. (See Figure 19–3). In all cases, a covering memorandum identifying the work and requesting the required computations should accompany input data.

(g) See Figure 19–4 for sample listing of output for a closed traverse computation.

(h) All requests for computations should be addressed to:

Bureau of Electronic Data Processing
Pennsylvania Department of Highways
North Office Building
Harrisburg, Pennsylvania

Figure 19–1

COMMONWEALTH OF PENNSYLVANIA
Department of Highways
Bureau of Electronic Data Processing

FORM

TRAVERSE INPUT SHEET-HEADER

DISTRICT EDP COUNTY HOPEFUL LEG. ROUTE 2067 SECTION 14B LANE EB RUN 02

PROPERTY OWNER _____ DEED BOOK _____ PAGE _____ DEED AREA _____ DATE _____

HEADER CARD

	CO	LR	SECT	LANE	RUN	DATA TYPE	STATION	STARTING COORDINATES NORTHING	STARTING COORDINATES EASTING	STARTING STATION	ENDING COORDINATES NORTHING	ENDING COORDINATES EASTING
Column	1-2	3-6	7-9	10-11	12-13	14-15	16-23	24-33	34-43	44-51	52-61	62-71
	72	2067	14B	EB	02	7.0	0.00	20000.0000	20000.0000	70000	20000.0000	20000.0000

NO. 2 CARD

	CO	LR	SECT	LANE	RUN	DATA TYPE	16-24	OC	SI LE	C	A	NCRS	31-80
Column	1-2	3-6	7-9	10-11	12-13	14-15	16-24	25	26	27	28	29-30	31-80
	72	2067	14B	EB	02	7.1	ABDNSEWLR	1	0	1	1	15	

INSTRUCTIONS TO DESIGNER

HEADER CARD

A. Do not fill in columns 1-13. These will be coded at the Data Processing Center from data entered in heading. Fill in DEED information if applicable.

NO. 2 CARD

B. Column 25 - 0 if open traverse, 1 if closed traverse.
C. Column 26 - 0 if input by stations, 1 if input by course lengths.
D. Column 27 - 0 if no adjustment desired, 1 if adjustment desired.
E. Column 28 - 0 if no area desired, 1 if area desired.
F. Columns 29-30 - Enter total number of courses as shown on Cards B forms. - Limit of 99 courses.
G. Columns 31-80 - Leave Blank.

Prepared by Little Date June 15, 1964 Sheet 1 of 2

For EDP use:

EDP No. Test 1 Card Color Blue 5081 Code 28 Prog. No. 28.0.010

Processed by _____ Copies Shipped _____ Date _____

Figure 19–2

COMMONWEALTH OF PENNSYLVANIA
Department of Highways
Bureau of Electronic Data Processing

TRAVERSE INPUT-CARDS B

FORM

DATE June 15, 1964

DISTRICT EDP COUNTY HOPEFUL LEG ROUTE 2067 SECTION 14B LANE EB RUN 02

CO	LR	SECT	LANE	RUN	DATA TYPE	CRSE NO.	PI STATION OR LENGTH OF COURSE		BRG., DEFL., OR AZ. DEG.	MIN.	SEC.		RADIUS OF CURVE	SUB-TANGENT LENGTH	SIGN
1-2	3-6	7-9	10-11	12-13	14-15	16-17	18-25	26	27	28-30	31-32	33-34	35	36-43	44-51	52
72	2067	14B	EB	02	72	01	0+03195	B	N	064	15	00	E	0	0	0
72	2067	14B	EB	02	72	02	0+02845	B	N	051	02	40	E	0	0	0
72	2067	14B	EB	02	72	03	0+01870	B	N	042	17	10	E	0	0	0
72	2067	14B	EB	02	72	04	0+03817	B	N	048	53	40	E	0	0	0
72	2067	14B	EB	02	72	05	0+05289	B	N	036	12	40	W	0	0	0
72	2067	14B	EB	02	72	06	0+03819	B	S	056	05	00	W	0	0	0
72	2067	14B	EB	02	72	07	0+04422	A		2558	19	30		0	0	0
72	2067	14B	EB	02	72	08	0+01761	A		3288	44	30		0	0	0
72	2067	14B	EB	02	72	09	0+04281	B	S	077	08	30	W	0	0	0
72	2067	14B	EB	02	72	10	0+03602	B	S	038	48	30	E	0	0	0
72	2067	14B	EB	02	72	11	0+04419	B	S	009	30	40	E	0	0	0
72	2067	14B	EB	02	72	12	0+05812	D		007	09	10	R	0	0	0
72	2067	14B	EB	02	72	13	0+02410	D		042	10	40	L	0	0	0
72	2067	14B	EB	02	72	14	0+01873	B	S	074	51	30	E	0	0	0
72	2067	14B	EB	02	72	15	0+02823	B	N	073	24	10	E	0	0	0
					72											
					72											
					72											
					72											
					72											

Prepared by Little Date June 15, 1964 Sheet 2 of 2

EDP NO. Test 1

Figure 19-2A

INSTRUCTIONS TO DESIGNER

A. Columns 16-17 - Number courses, consecutively

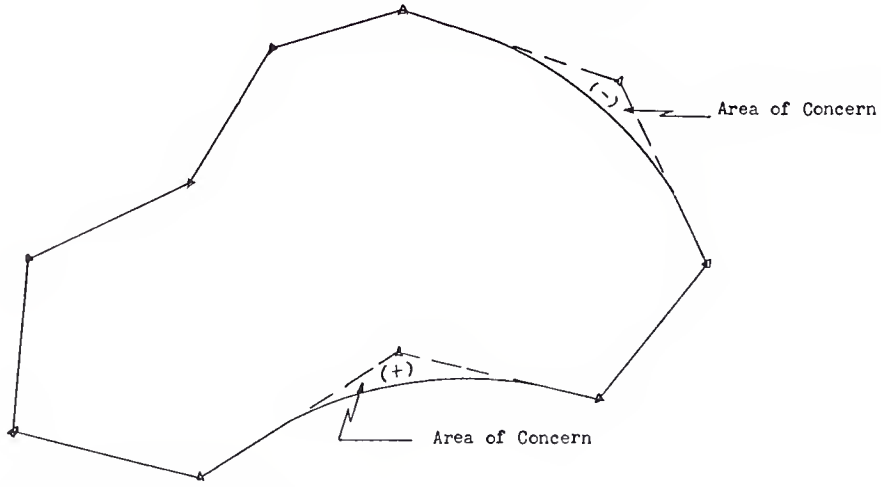
B. Column 26 - A if azimuth angle, B if bearing angle, D if deflection angle

C. Column 27 - N if north, S if south, if azimuth or deflection angle - Leave Blank

D. Column 35 - E if east, W if west, L if left defl., R if right defl. Leave Blank if azimuth

E. Column 52 - Sign of Area for Arcs. - 0 if minus, 1 if plus

Handling arcs in area computations



a. Carry traverse around Sub-tangents.

b. Enter radius and Sub-tangent length in proper column on same line as course length and angle.

c. Indicate deduction by 0 or addition by 1 in CC 52.

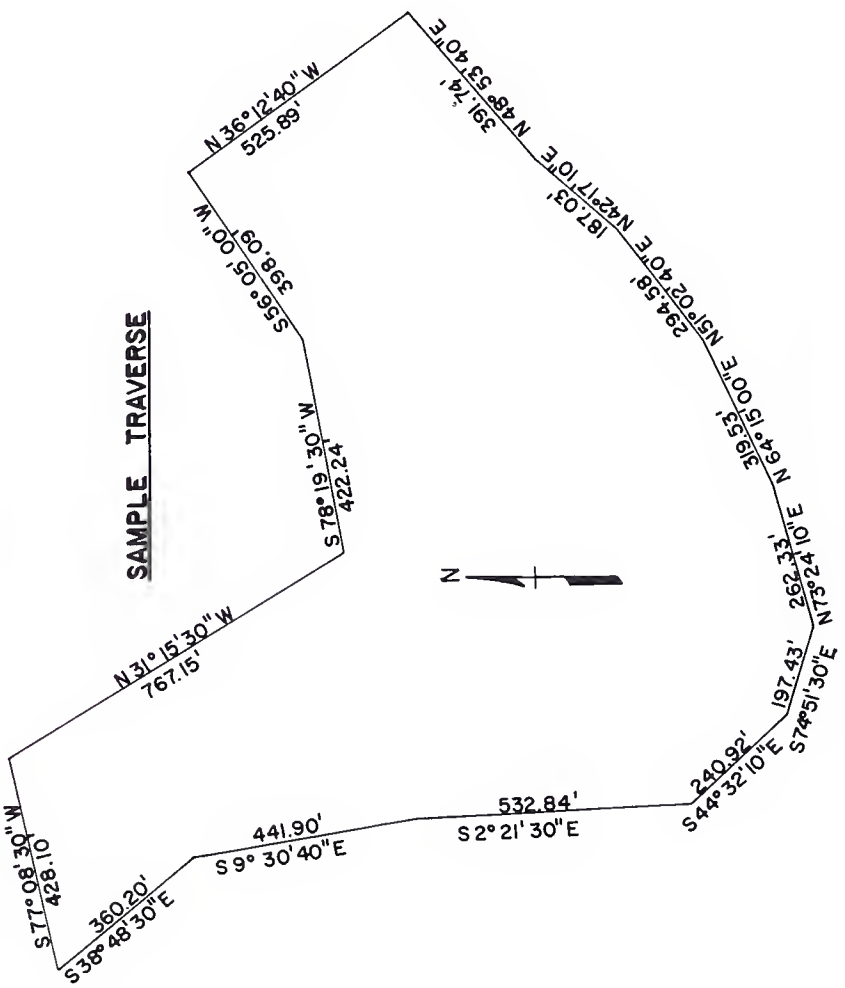

SAMPLE TRAVERSE
N
N 36° 12' 40" W
525.89'
N 48° 53' 40" E
391.74'
N 42° 17' 10" E
187.03'
N 57° 02' 40" E
294.58'
N 69° 15' 00" E
315.53'
N 73° 24' 10" E
262.33'
S 74° 51' 30" E
197.43'
S 44° 32' 10" E
240.92'
S 2° 21' 30" E
532.84'
S 9° 30' 40" E
441.90'
S 38° 48' 30" E
360.20'
S 77° 08' 30" W
428.10'
N 31° 15' 30" W
767.15'
S 78° 19' 30" W
422.24'
S 56° 05' 00" W
398.09'

Figure 19–3

Figure 19–4

TRAVERSE COMPUTATIONS

CO 72 LR 2067 SECT 148 LANE E8 RUN 2 DATA TYPE 14 STA 700+ 0. 6/24/64

OPEN OR CLOSED 1.0 STATION OR COURSE LENGTH 1.0 IS ADJUSTMENT DESIRED 1.0 IS AREA DESIRED 1.0 NUMBER OF COURSES IS

OPEN OR CLOSED	0.0 IS OPEN TRAVERSE	1.0 IS CLOSED TRAVERSE
STATION OR COURSE LENGTH	0.0 IS STATION INPUT	1.0 IS COURSE LENGTH
IS ADJUSTMENT DESIRED	0.0 IS NO ADJUSTMENT	1.0 IS ADJUSTMENT DESIRED
IS AREA DESIRED	0.0 IS NO AREA	1.0 IS AREA DESIRED

ANGLES ARE GIVEN IN BEARING- AZIMUTH- AND DEFLECTION FROM COURSE BACK

UNADJUSTED TRAVERSE OUTPUT

CD 72 LR 2067 SECT 148 LANE E8 RUN 2 DATA TYPE 14 STA 700+ 0. 6/24/64

COURSE NO	P1 STA OR ACCUM DIST	BEARING D M S	AZIMUTH D M S	DEFLECTION D M S	COURSE LENGTH	COSINE ON	SINE OE	COORDINATES N	E
9	3734.35	ST7 8 30W	257 8 30	71 35 60L	428.10	-0.2225393	-0.974923T		
						-95.27	-417.36	201397.20	199067.92
10	4094.55	S38 48 30E	141 11 30	115 57 0L	360.20	-0.7792474	0.6267163		
						-280.68	225.74	201116.51	199293.67
11	4536.45	S 9 30 40E	170 29 20	29 1T 50R	441.90	-0.9862538	0.1652376		
						-435.83	73.02	20068D.69	199366.68
12	5069.29	S 2 21 30E	17T 38 30	7 9 10R	532.84	-0.9991531	0.0411478		
						-532.39	21.93	200148.3D	199388.61
13	5310.21	S44 32 10E	I35 27 50	42 10 40L	240.92	-D.7128D92	0.7013580		
						-171.73	168.9T	199976.57	19955T.58
14	5507.64	S74 51 30E	105 8 30	30 19 20L	197.43	-0.2612073	0.9652827		
						-51.5T	190.58	199925.00	199748.16
15	5T69.9T	NT3 24 10E	73 24 10	31 44 20L	262.33	0.2856414	0.9583366		
						74.93	251.40	199999.93	199999.56

ERROR / DIST 0.45 5T69.97

PRECISION RATIO ONE IN 12813.11 200000. 200000.

TRAVERSE ADJUSTED BY TRANSIT RULE

CD T2 LR 2067 SECT 148 LANE E8 RUN 2 DATA TYPE 14 STA 700+ 0. 6/24/64

COURSE NO	P1 STA OR ACCUM DIST	BEARING D M S	AZIMUTH D M S	DEFLECTION D M S	COURSE LENGTH	COSINE ON	SINE OE	COORDINATES N	E
9	3734.28	S77 8 49W	257 8 49	T1 36 1L	428.D5	-0.2225606	-0.9749189		
						-95.27	-41T.32	201397.24	199068.26
1D	4094.50	S38 49 16E	141 10 44	115 58 5L	360.21	-D.7792054	0.6267686		
						-280.68	225.77	201116.56	I99294.03
11	4536.39	S 9 31 23E	170 28 37	29 I7 53R	441.89	-0.9862501	0.1652597		
						-435.82	73.03	200680.74	19936T.05
12	5069.22	S 2 22 11W	182 22 I1	11 53 35R	532.83	-0.9991528	0.0411534		
						-532.38	21.93	200I48.36	199388.98
13	5310.15	S44 32 55W	224 32 55	42 1D 43R	240.93	-0.7I27611	0.7014069		
						-I71.73	168.99	199976.64	199557.97
14	55DT.60	ST4 52 1E	105 7 59	119 24 56L	I9T.45	-0.2611739	0.9652918		
						-51.5T	190.60	199925.07	199748.57
15	5769.96	N73 23 59E	73 23 59	31 43 60L	262.36	0.2856150	0.9583444		
						74.93	251.43	200000.	200000.00

ERROR / DIST 0.45 5T69.96

PRECISION RATIO ONE IN 12813.1I 200000. 20000D.

AREA IN SQUARE FEET 2119567.000

AREA IN ACRES 48.66

INDEX

A

Page No.

Aerial Surveys (See Surveys)
Alignment, Design Criteria ... 3–1
Alignment, Surveys (See Type of Survey)
Arches, Semicircular (See Bridge and Culvert Site Surveys)

B

Bench Levels, Preliminary ... 8–2
Bench Marks, Construction ... 11–2
Bench Marks, Final ... 13–3
Bench Marks, U.S.C. & G.S., Preservation of ... 11–4
Borrow Pits (See Surveys)
Bridge and Culvert Site Surveys (See Survevs)
Bridge Site, Stakeout ... 11–4
Bridge Sites—Photogrammetry ... 9–2

C

Cars, Employes, Personal ... 17–5
Cars, Personnel, Care of ... 16–1
Center Line, Construction Survey ... 11–1
Center Line, Final Chaining (See Chaining)
Center Line, Preliminary Survey ... 8–1
Chain Surveys (See Surveys)
Chaining, Final, Survey and Pavement Center Line ... 13–1
Clearance, Vertical (Design Criteria) ... 3–3
Condemnation of Right of Way Surveys (See Surveys)
Construction of Surveys (See Surveys)
Contents, Table of ... ii
Corps, Organization for
    Construction Surveys ... 2–3
    Final Surveys ... 2–3
    Geodetic Surveys ... 2–3
    Preliminary Surveys ... 2–2
    Traverse Survey ... 2–2
Cross-Sections (See Type of Survey under Surveys)
Crossings, Grade, Railroad ... 4–4
Culverts (See Surveys)
Curve Procedure, Preliminary Survey ... 8–3
Curves, Spiral ... 11–5
Curves, Transition ... 8–4

D

Daily Survey Report (See Reports—Form)
Data Processing (See Electronic)
Design Speed (Design Criteria) ... 3–1
Dumpy Level (See Instruments)

E

	Page No.
Electronic Data Processing	
Adjustment Methods	19–1
Address for Computation Requests	19–2
Area for Closed figures	19–1
Input Data Required	19–1
Notes, General	19–1
Output Data	19–1
Traverse Computations	19–1
Eminent Domain Law and Amendment, Waiver of 10-Day Notice	1–1
Equipment, Care and Use of	16–4
Equipment, Chain Surveys	4–1
Equipment, Corps	16–6
Equipment, Transporting of	16–1
Expenses, Personal (See Reports—Forms)	

F

Figures (See Figures Index)	19–15
Final Surveys (See Surveys, or Corps, Organization of)	
Forms (See Reports—Forms)	

G

Geodetic Surveys (See Surveys)	
Grade Sheets (See Construction Surveys)	
Grades (Design Criteria)	3–2

I

Information, Useful (See Index—Useful Information)	
Instructions, General	1–1 thru 1–8
Instruments, Adjustments of	
Dumpy Level	16–2
Transit	16–3
Wye Level	16–3
Instruments, Precautions in handling	16–5
Introduction	i

M

Mapping (See Aerial Surveys)	
Meridian—Observation of Polaris	
Any Hour Angle	8–11
Elongation	8–9
Meridian—Observation of the Sun	8–12
Meridians, Convergence of	8–8

N

	Page No.
Notebooks, Care of	15–1
Symbols, Abbreviations	15–2
Symbols, Curve Data	15–3
Notebooks, Construction Survey	11–1
Notes, Chain Survey, Railroad Crossing	4–4

P

Photography (See Aerial Survey)
Preliminary Surveys (See Surveys) See Corps, Organization of)
Procedure (See Type Survey)

R

Railroad Crossings (See Crossings)	
Reconnaissance Surveys (See Surveys)	
Reports—Forms, List of	17–1
Daily Survey Report, Form 419-A	17–2
Employes Personal Car, Form 55-S	17–5
Expense Statement, Form 55	17–2
Receipt for Lodging and/or Meals, Form 204	17–2
Record of Equipment Operation, Form 805	17–2
Survey Charges, Form 401	17–1
Right of Way, Condemnation of (See Surveys)	

S

Shoulders, Width of (Design Criteria)	3–3
Sight Distance (Design Criteria)	3–3
Special Structures (Construction Survey)	11–4
Spiral Curves (See Curves)	
Stake-out, Bridge Site (See Bridge Site)	
Stakes, Placement of (Construction Survey)	11–2
Superelevation Controls (Spiral and Non-Spiral) (Design Criteria)	3–4
Interstate Class 1 and Ultimate Class 1	3–5
Class 2 and Class 3	3–6
Class 4 and Class 5	3–7
Supplies, (List of Corps)	16–6
Surveys	
Aerial	
Geodetic	9–2
Photogrammetric Mapping	
Area Studies	9–2
Borrow Pits	
Cross Sections, Final	12–2
Procedure	12–1

Page No.

Bridge and Culvert Sites

Alignment 10–2
Arches, Semicircular 10–16
Data Required 10–3
Hazard or Obstruction 10–1
Triangulation 10–21
Trilateration 10–22
Water Courses 10–1
Water Way, Determination of 10–5
Data Required 10–6
Maximum Flood Discharge, Determination of 10–7

Chain

Culverts and Bridges 4–3
Data Required 4–3
Equipment 4–1
Grade Crossings, Railroad 4–4
Notes 4–4
Procedure 4–2
Purpose 4–1
Structure Separation 4–4

Construction

Bench Marks 11–2
Bench Marks, U.S.C. and G.S. Preservation of 11–4
Center Line, Locating 11–1
Cross-Sections 11–3
Curves—Spiral 11–5
Grade Sheets, Preparation of 11–3
Notebooks, Preparation of 11–1
Purpose, General 11–1
Stakes, Placement of 11–2
Stakeout, Bridge Site 11–4
Structures, Special 11–4

Condemnation of Right of Way

Abandoned, Canals and Railroads 14–3
Proposed Highway, Future 14–4
Public Utility Commission Order, Within limits of 14–4
Purpose, General 14–1
Ultimate 14–1
Unobstructed View 14–3

Final

Alignment 13–1
Bench Marks 13–3
Chaining, Survey and Pavement Center Line 13–1
Cross-Sections, Procedure 13–2
Pay Quantities, Measurements for 13–3
Purpose, General 13–1

Page No.

Low Cost Construction

Alignment 5–1
Cross-Sections 5–3
Profile 5–3
Purpose, General 5–1
Topography 5–2

Preliminary

Azimuth—Altitudes of Sun 8–15
Bench Levels 8–2
Center Line 8–1
Convergence of Meridians 8–8
Cross-Sections 8–6
Curve Procedure 8–3
Meridian—Observation of Polaris Any Hour Angle 8–11
Meridian—Observation of Polaris, Elongation 8–9
Meridian—Observation of Sun 8–12

Reconnaissance 6–1

Traverse 7–1

T

Tables (See Tables Index) 19–14
Topography (See Type Survey) .....
Transit, Adjustment of (See Instruments) .....
Transition Curves (See Curves) .....
Traverse Survey (See Surveys) (See Corps, Organization of) .....
Triangulation (See Bridge and Culvert Site Surveys) .....
Trilateration (See Bridge and Culvert Site Surveys) .....

U

Useful Information (See Index—Useful Information) 19–13

W

Waiver of 10-Day Notice 1–7
Water Courses (See Bridge and Culvert Site Surveys) .....
Water Way (See Bridge and Culvert Site Surveys) .....
Wye Level, Adjustment of (See Instruments) .....

INDEX

USEFUL INFORMATION

	Page No.
Azimuth by Altitudes of the Sun (Notes)	8–15
Circles, Properties of	18–8
Circles, Solution of a Segment	18–18
Construction Payment—Items and Basis	18–1
Construction Payment—Reference Notes	18–4
Conversion Factors	18–33
Curb Returns, Method of Staking	18–20
Curve Data, Cord Method	18–19
Curve Data, Recording of	8–3
Curves, Vertical—Determining Grades	18–21
Design	
Grades, Maximum	3–2
Shoulders, Minimum Width	3–3
Sight Distance (Horizontal and Vertical)	3–3
Speed and Width of Pavement	3–1
Equipment, Miscellaneous	4–1
Equipment—Supplies	16–6
Equivalents, Miscellaneous	18–8
Geometrical Solids—Volumes and Surface	18–15
Heads of Water in Feet, pressures in various units	18–9
Meridian, Convergence	8–8
Meridian—Observation on Polaris, Any Hour Angle	8–11
Meridian—Observation on Polaris, Elongation	8–9
Meridian—Observation the Sun	8–12
Reports—Forms	17–1
Superelevation Controls	
General	3–4
Interstate Class 1 and Ultimate Class 1	3–5
Class 2 and Class 3	3–6
Class 4 and Class 5	3–7
Symbols, Abbreviations	15–2
Triangles—Oblique, Formulas for Solution	18–14
Triangles—Right, Formulas for Solution	18–13
Trigonometric Functions	18–11
Trigonometric Functions—Natural	18–12

INDEX

TABLES

	Page No.
Bar Weights—Round and Square, Areas	18–23
Board Measure	18–28
Circles—Area and Circumference	18–22
Conversion Factors—Common	18–33
Conversion Tables	18–5
Converting Inches into Decimals of a foot	18–23
Curves—27° to 55° (Actual Arc Method)	15–13
Decimals of an Inch and a Foot	18–24
Geodetic Surveys—Classification and Accuracy Standards	
Triangulation	9–4
Traverse	9–6
Leveling	9–7
Miles and Tenths Reduced to Feet	18–26
Minutes in Decimals of a Degree	8–14
Ounces Reduced to Decimals of a Pound	18–24
Parallax in Altitude—Correction	8–14
Pavement Surface—Area	18–27
Photogrammetry—Ratio of Map Scale to Photography	9–3
Refraction—Correction	8–14
Thermometric Equivalents	18–27
Trigonometric Functions—Natural	18–12
Waterway—Bridges	
Run-off, Maximum—Various Drainage Areas	10–6
N = .030	10–8
N = .035	10–9
Values of "C"—Kutters Formula	10–10
Velocity of Water—Feet per second	10–11
Data for semicircular Arches	10–15
C. M. Pipe—Arches—Sizes and Weights	10–21
Wire Gauge	18–29

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INDEX FIGURES

	Page No.
Arches, Semicircular—Calculating Waterway Area	10–14
Azimuth by Altitudes of the Sun (Notes)	8–15
Construction Stake-out	15–9
Circles, Solution of a Segment	18–18
Cross-Sections—Preliminary and Final	15–8
Curb Returns—Method of Staking	18–20
Curve Data, Cord Method	18–19
Electronic Data Processing	
Traverse Input Sheet—Header	19–3
Traverse Input—Cards B	19–4
Arcs in Area Computations	19–5
Traverse—Sample	19–6
Output—Traverse Computations Sample	19–7
Flat Chaining	15–10 and 15–11
Foundation Test Borings	10–20
Geometrical Solids—Volumes and Surface	18–15
Measuring Methods	
Guard Fence, Pipe, Tile, Underdrain, etc.	18–32
Intersections, Excavation (Ditches and Drives)	18–30
Pay Quantities for Intersection Radius, Driveways, Widened Curves	15–12
Pipe Removal and Benching	18–31
Test Holes for Bridge Foundations	10–19
Topography	
Built-up Sections	15–5
Open Country	15–6
Stream Area	15–7
Transit Notes	15–4
Triangles—Oblique, Formulas for Solution	18–14
Triangles—Right, Formulas for Solution	18–13
Triangulation Net—Bridge Site	10–23
Trigonometric Functions	18–11
Trigonometric Functions—Natural	18–12